Living with the Alabama-Mississippi shore

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Preface

People have lived at the shore for thousands of years, and throughout that time nature has taught lessons about how shorelines change. Sometimes these lessons have been subtle, barely noticeable, but more often the lessons have been of the "hard knocks" variety in which property and lives were lost. This is the case for Alabama and Mississippi. No other part of the American coast has suffered more severely from recent hurricanes. Part of the presentation that follows is an examination of the dangers disguised by the tranquility and beauty of nature.

If you stand on a sand dune on a sunny day and look across the beach toward the Gulf of Mexico, it is difficult to imagine the possibility of a hurricane or how destructive such a storm can be. It is just as difficult to imagine that the coast does not remain just as we see it. Dr. George Crozier of the Dauphin Island Marine Laboratory has described this coast as a double-edged sword—an attraction because of access to some of the country's finest beaches, bays, and barrier islands, and a threat because people are deciding to remain on the coast. Sunny-day decisions are leading to dangerous development.

The sandy shoreline of the Gulf Coast is a dynamic, ever-changing environment that often does not interact well with the trappings of man. The exploitation of this dynamic coastal area is being carried out at an ever-increasing rate. First came the harbors and ports that required channel maintenance; then came the seashore resorts that attracted construction on the retreating shorelines. Earlier generations of Americans were either wise enough to locate properly or resigned to watch their homes fall victim to shoreline retreat; but modern coastal developers are more inclined to build to the very edge of the sea, then find it necessary to attempt to stop shoreline retreat in order to extend the lifespans of buildings along the shore. The long-range results of such efforts, however, are economic and environmental calamity. Such results are visible along the New Jersey, South Florida, and other older coastal development shorelines. Coasts strewn with rubble from destroyed "protective" structures attest to the fact that humanity's success in holding back nature for its own ends does not necessarily enhance our surroundings or the quality of our life.

Our goal is to help Gulf Coast residents learn to live in harmony with nature at the shoreline and to understand fully the consequences of doing otherwise. This book is not meant to discourage development; we hope, rather, that it encourages proper, limited development. Although certain natural areas warrant protection from development, preservationism is an unrealistic philosophy to follow on all of the coast, especially when a development pattern is already established on much of it. Unrestricted development, however, endangers coastal residents and resources. The public should become aware of and concerned about our important coastal resources in order to conserve them.

The present volume is one of a series being published by Duke

University Press. The series will eventually cover all coastal states. The first volume, entitled *From Currituck to Calabash: Living with North Carolina's Barrier Islands*, is concerned with the barrier island coast of North Carolina. The success of this book in promoting safe and sound use of the North Carolina islands led to support from federal agencies to produce the other books. Most of the state books are closely patterned after *From Currituck to Calabash*. Several sections, such as the ones on safe construction and the philosophy of shoreline conservation, are repeated here with minor revisions. With the use of this book we hope to aid Gulf Coast citizens in evaluating the safety and longevity of various portions of their shore. We don't want anyone to be in the frustrating and even tragic position of saying "How was I to know that . . .?"

As part of this coastal safety series Van Nostrand-Reinhold Company published *Coastal Design: A Guide for Builders, Planners, and Homeowners* by Orrin H. Pilkey, Sr., Walter D. Pilkey, Orrin H. Pilkey, Jr., and William J. Neal in 1983. *Coastal Design* emphasizes coastal construction principles to a much greater extent than the individual state books. We recommend that the prudent coastal citizen also obtain this reference.

We came to write this book from several different backgrounds. Wayne Canis teaches geology at the University of North Alabama and the Marine Environmental Sciences Consortium at the Sea Lab on Dauphin Island. He has seen first-hand the "before" and "after" Hurricane Frederic conditions on Perdido Key, at Gulf Shores, and along the Fort Morgan Peninsula, on Dauphin Island, and Alabama's mainland shore. Bill Neal, a geologist from Grand Valley State College in Michigan, has worked on the barrier island coasts of the Carolinas and Georgia where he formerly lived. He is familiar with shoreline erosion problems in the Great Lakes that are similar to those of the Gulf Coast embayments. Orrin Pilkey, Jr., coastal geologist and geological oceanographer at Duke University, has addressed shoreline problems from Texas to New England. After Hurricane Camille, he was on the business end of a shovel helping his parents dig out and clear the debris from their Waveland, Mississippi, home. Orrin Pilkey, Sr., experienced that hurricane and learned why hurricane-resistant construction and proper site selection is a necessity for the well-being of all Gulf Coast residents. As a civil engineer, his knowledge and experience provided a basis for chapter 6 on coastal construction.

The information presented here represents the summation of the work of many investigators, too numerous to mention, but to whom we owe a sincere thanks. We also were helped by many people who live and work along the shore, including representatives of various state agencies. We express special thanks to David Barley, Carlyle Blakeney, Jerry Burns, George Crozier, Joe Gill, Stan Hecker, Myrt Jones, Ervin Otvos, Doug Parker, Cy Rhode, and Malcolm Ware. We are grateful for the cooperation, insights, and concerns we acquired from them. We appreciate the cooperation and assistance of the following agencies: Alabama Coastal Area Board; Alabama Department of Environmental Management; Alabama Department of Economic and Community Affairs; Mississippi-Alabama Sea Grant Consortium, Bureau of

Marine Resources—Mississippi Marine Conservation Committee; Marine Environmental Sciences Consortium—Dauphin Island Sea Lab; U.S. Army Corps of Engineers—Mobile District; U.S. Geological Survey National Cartographic Information Center—National Space Technology Laboratories; National Park Service—Gulf Islands National Seashore; Civil Defense offices of Baldwin and Mobile counties, Alabama; Jackson County, Mississippi, Disaster Emergency Services; other local offices; and the National Audubon Society. Appendix B contains the addresses and phone numbers of these and other agencies.

The overall project of producing these books is an outgrowth of initial support from the National Oceanic and Atmospheric Administration through the Office of Coastal Zone Management. The project was administered initially through the North Carolina Sea Grant Program. Support from the Federal Emergency Management Agency allowed us to expand the book project to all coastal states. The technical conclusions presented herein are those of the authors and do not necessarily represent those of the supporting agencies.

We owe a debt of gratitude to many individuals for support, ideas, encouragement, and information for the series project. Peter Chenery of the North Carolina Science and Technology Research Center and Richard Foster of the Federal Coastal Zone Management Agency gave us encouragement and support at critical junctures of this project. Doris Schroeder has helped us in many ways as Jill-of-all-trades over more than a decade. Mike Robinson of the Federal Emergency Management Agency worked hard to help us chart a course through the shifting channels of the federal bureaucracy. Dennis Carroll, Jim Collins, Jet Battley, Peter Gibson, Melita Rodeck, Richard Krimm, Chris Makris, and many others also helped us through the Washington maze. Special thanks are extended to Bette Weerstra for typing the manuscript, and to Barbara Gruver for drawing the line illustrations. Finally, we are in the debt of many coastal residents, fellow geologists, coastal engineers, and state and local government officials too numerous to name who enthusiastically provided us with a wealth of data, ideas, and "war stories."

We dedicate this work to all who have helped, and to all who come to enjoy the coasts of Alabama and Mississippi.

William J. Neal / Orrin H. Pilkey, Jr. /
series editors
October 1984

1. A coastal perspective

Wrapped around the Gulf of Mexico is a band of real estate known as the "Sun Belt." Like a rainbow attracting gold seekers, the Sun Belt states are drawing increasing numbers of tourists and retirees as well as industries with their associated work forces. The coastal zone is where this rainbow touches the sea; and from Key West to the Rio Grande, this is where the most rapid development is taking place.

Increased development brings with it the potential to destroy the amenities that were its wellspring, namely the natural environment and the living resources of that environment. Indeed, we can smother the proverbial gold-producing goose and unknowingly place ourselves at risk while pursuing the rainbow of our dreams and goals. Building and living in the coastal zone is a risk—a risk that some are taking without knowing the available facts.

The purpose of this book is to provide a starting point on the road to understanding the environment, the risks, and the ways to conserve the former while reducing the latter, particularly when buying property or building near the shore. The range of topics included are aimed, however, at a wider audience because everyone has a stake in the coast and its future. Residents, tourists, hunters and fishermen, those who earn their daily bread in the commerce and industry of the coast, and every taxpayer in Alabama and Mississippi will gain or lose according to the direction taken by coastal development.

Top of the rainbow: a brief description of the coast

The Alabama-Mississippi coast lies at the apex of the Gulf-Sun Belt arch. The straight-line distance of state-to-ocean border is not great, but the total shoreline distance around islands, along sounds, and into embayments approaches 1,000 miles (fig. 1.1). Alabama's shore is the longest with 607 miles of tidal shoreline, of which 46 miles are sandy beach. Mississippi has 359 miles of tidal shoreline, much of which is beach, including man-made beaches.

Barrier islands form about 70 miles of the leading edge of the Gulf Coast. These are the long, thin islands that parallel the mainland coast. Even what is now mainland coast from Perdido Key through the Fort Morgan Peninsula may once have been a chain of barrier islands (fig. 1.1). This stretch of coast may be treated as similar to modern barrier islands as far as many processes and their associated hazards are concerned. Much of the Mississippi mainland shore is an old coastal barrier ridge system that formed during an interglacial high stand of sea level, probably more than 35,000 years ago. All Alabama and Mississippi ocean-facing shorelines are very dynamic. They are constantly altered by storms, changing shape or elevation as they absorb wave energy or are flooded and washed over. As their sand is moved about, the barrier islands migrate, shifting laterally and somewhat landward through time as the world's sea level rises. Part of Petit Bois Island was once in Alabama waters, but it has moved laterally and is now completely in Mississippi. Could the island be making a political comment? The lighthouse at the mouth of Mobile Bay was built on a small sand island. The island's sand migrated, leaving the

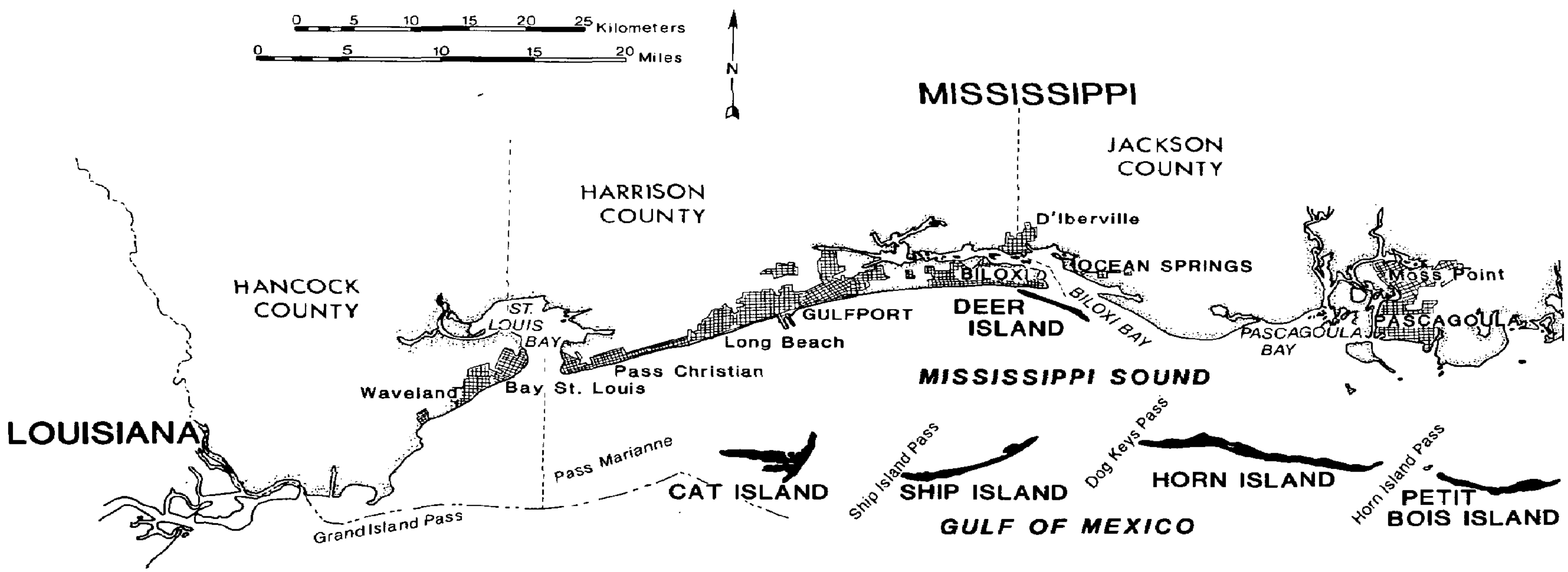
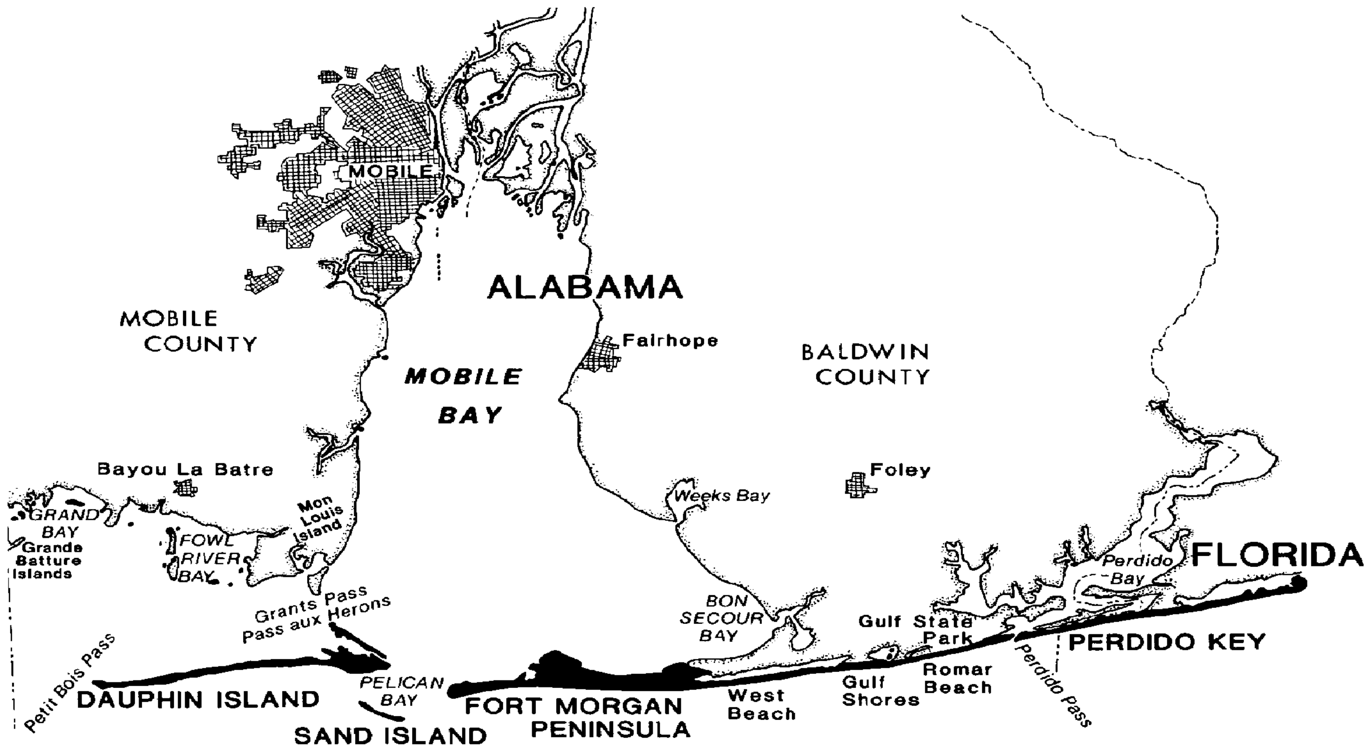


Fig. 1.1. Index map of the Alabama-Mississippi coast.


MOBILE
ALABAMA
MOBILE COUNTY
MOBILE BAY
Fairhope
BALDWIN COUNTY
Bayou La Batre
Foley
GRAND BAY
Grande Batture Islands
FOWL RIVER BAY
Mon Louis Island
Weeks Bay
FLORIDA
Perdido Bay
Grants Pass
Pass aux Herons
BON SECOUR BAY
Gulf State Park
PERDIDO KEY
Petit Bois Pass
DAUPHIN ISLAND
PELICAN BAY
FORT MORGAN PENINSULA
West Beach
Gulf Shores
Romar Beach
Perdido Pass
SAND ISLAND

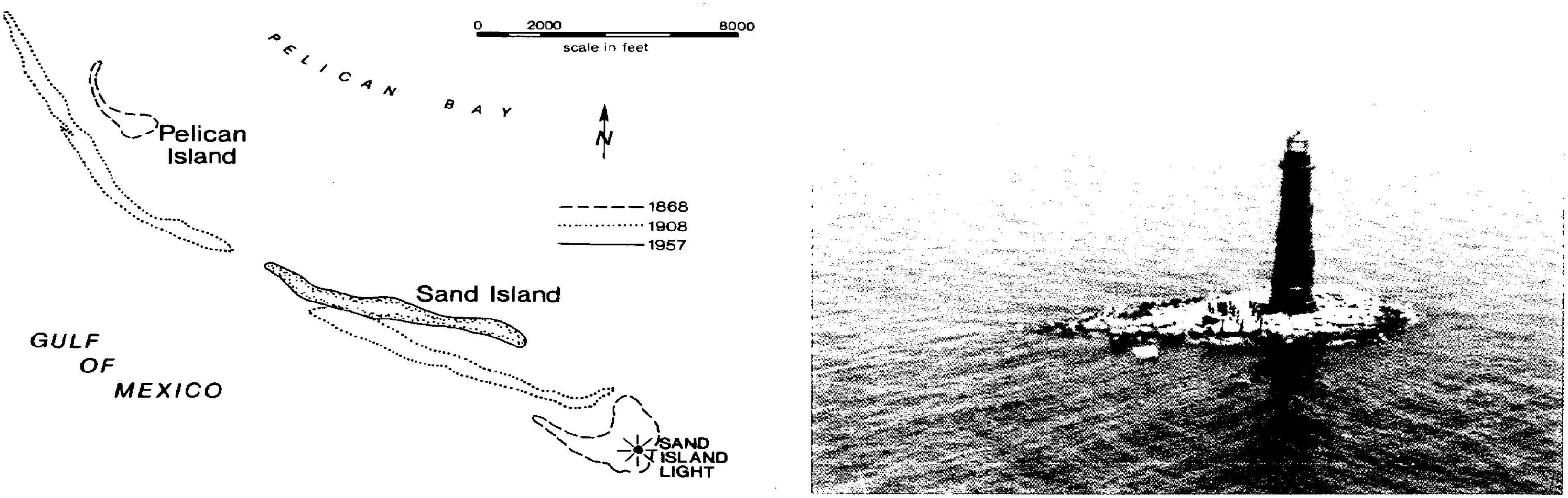


Fig. 1.2. Sand Island Lighthouse: (a) map of island migration from 1868 to 1957, (b) the lighthouse today is no longer on an island. Photo by Bill Neal.

lighthouse with its feet in the bay (fig. 1.2). Similarly, mainland shoreline positions retreat landward as sea level rises.

The barrier islands will provide a point of reference throughout the following chapters, both for the discussion of natural processes as well as comparison between different approaches to coastal land use. Alabama has chosen to develop much of its ocean-facing barrier shore, whereas Mississippi's barrier islands remain undeveloped. This usage is more an accident of nature than a reflection of any early, farsighted land-use plans. Mainland access is feasible for Alabama's barrier beaches, but the Mississippi islands lie 3.5 to 12.5 miles offshore.

One small Mississippi island was a popular resort in the 1920s. The Isle of Caprice between Horn Island and Ship Island emerged by a process of offshore bar buildup around the turn of the century. Once exposed, the island built up with dunes and vegetation, but by the late 1920s it was eroding and by 1939 had faded into history as a resort. A hurricane in 1947 removed what was left of the island, providing a lesson about the stability of such islands for development. The lesson, like the island, has been lost to later developers of parts of Dauphin Island, West Beach, and similar areas.

Between the barrier islands and the edge of the mainland is Mississippi Sound, more like an embayment than an open gulf. The sound is an important ecosystem that supports the food chain essential to the seafood fisheries. This broad area of shallow water behind the barrier islands adds to the protective cushion against hurricane waves.

The mainland shore of the sound is a complex of shoreline types, including barrier-like islands that mark the positions of former ridges (drowned as the sea level rose), marsh islands, tidal marshes, low bluffs, and some narrow, sandy beaches, sometimes cutting back into the adjacent pine forests. These shores are of low wave energy in comparison to the wide, more coarse-sanded, ocean-facing beaches of the barrier islands; but many of them are eroding, and all are subject to flooding.

A series of small bays (St. Louis, Biloxi, Pascagoula, Point Aux Chenes, Grand, Fowl River) of still lower wave energy and lower salinity extend into the mainland from the sound. Their shores also are subject to wave erosion and flooding. Their tidal marshes are important breeding grounds for marine organisms.

Mobile Bay, because of its great size and location, behaves oceanographically as a separate system from Mississippi Sound. Mobile Bay's shores are similar to those of Mississippi Sound, however, including widespread marsh, some high-bluffed areas, a few narrow, sandy beaches, and extensive developed shoreline behind artificial bulkheads.

Little Lagoon, Perdido Bay, Wolf Bay, and the freshwater bodies north of Gulf State Park also have low-energy shorelines that are low-lying and subject to flooding.

The rich contrast of shoreline types, of open Gulf to sound to bay or lagoon, of salinities, and scenery make this coastal zone one of the most attractive in America. The history of development of this beautiful coast is a long passage through 450 years of fortification, logging, farming, and fishing, until the mini-boom of the 1940s and beyond. Recreational development dates back to the

1830s and beyond when New Orleans residents began building summer homes on the Mississippi coast. By the 1890s sea bathing, fishing, and boating were building a resort reputation, but in a southern tradition of verandas and camps. The latest and most profound burst of development began in the 1950s.

Southern Riviera or New Jersey of the South?

As new centers of development or resorts arise, comparisons with existing famous places are in order. So it is that Pass Christian was once called the "Saratoga of the South," and Mississippi's "Gold Coast" is not a unique name for it conjures up images of Mediterranean beaches. Gulf Shores–Perdido Key is affectionately known as the "Redneck Riviera," again with a Mediterranean connotation, and the Riviera theme is widespread. A boast of the "world's whitest beaches" also is good advertising copy.

The Alabama-Mississippi shores need no comparisons, put-ons, or put-downs because they are a unique and rich resource. The shoreline running from the Florida Panhandle through the great sounds and embayments to the delta country of Louisiana stands alone and holds something for everyone. Unlike the resorts of the upper and mid-Atlantic states, the Gulf Coast's shores offer year-round fare.

But all is not going well with our coastal development. We can clearly see where we are heading, because others have been there before us. By studying the histories of other developed shorelines, Alabama and Mississippi can determine which decisions affecting development were proper and which were not. On the New Jersey and southern Florida coasts, there have been numerous environmental crises and a great deal of property loss because residents have failed to recognize the basic, natural processes of the shoreline. Some good may still come from these losses if they serve to guide today's developers away from past mistakes. Consider the New Jersey coast.

New Jerseyization: man's mistakes

On the New Jersey coast, environmental crises and property losses have resulted when residents, planners, and developers failed to recognize the basic, natural processes of the shoreline. Those losses should serve to guide today's developers away from past mistakes. We will call such damaging development trends *New Jerseyization* (fig. 1.3).

New Jersey's shoreline development began around 1800 with improved access and accommodations. Development proceeded very rapidly because of the proximity of Philadelphia and New York. Hotels and cottages were crowded together on every available piece of land, with little thought about the safety of the site. Often these were not even as well-built as inland buildings, despite the fact that the forces they would have to endure would be much greater. This development was soon threatened by natural coastal processes. People were concerned that the beaches seemed to be eroding away. New Jersey often chose to armor its shoreline in order to protect the beaches and development. Seawalls, bulkheads, groins, and jetties were built.

Today the remains of many of the protection schemes clutter the shore. In some places the beach has completely disappeared. A trip to the New Jersey shore at Cape May or Monmouth Beach would be worthwhile for every Gulf Coast resident because it conveys a more dramatic message than the pages of any book.

New Jerseyization is not only a problem of destroyed beauty (after all, some prefer to see a hot dog stand on the beach rather than a grass-covered dune). It also is a serious threat to coastal residents. The threat is basically in the following 5 areas.

Hurricanes. Where there is the constant threat of hurricanes, lives and property are endangered by unsafe construction and the use of hazardous building sites. Unfortunately, development on the Gulf Coast has not proceeded from the safest to the less safe sites. Often the most eager builders have owned the most dangerous shoreline property. Poor construction quality, which is independent of the safety of a building site, also is a danger.

Increasing costs. The burgeoning seawalls on the shores of the Gulf and bays cost a lot of money. The New Jersey experience shows that it is not only the initial costs of shoreline protection that are high; maintenance also is expensive, and continuous.

Pollution. Improper waste disposal threatens the health of coastal citizens and destroys the natural resources that support the local marine fishing industry.

Environmental destruction. The beach—the very environment we rush to the shore to enjoy—is ultimately destroyed when overdeveloped. Scenic dunes, maritime forests, and marsh habitats gradually disappear. The alteration of the environment is the most striking aspect of New Jerseyization. Beach-saving devices work only temporarily at best. Where seawalls are built, the beach is eventually lost. Old beach resorts in New Jersey and South Florida have no beaches at all except where sand has been pumped in. In addition, beach repair is done at great cost to the taxpayer. The latest 15-mile beach restoration project in Miami Beach, begun in 1977, eroded the public coffers by $68 million.

Fig. 1.3. New Jerseyization. Photo by Orrin Pilkey, Jr.

Reduced public access. Private development inevitably reduces access to the beach for the public, which must often nonetheless pay the bills for beach repairs. Access to the beach is frequently prohibited to all but adjacent property owners, and others must pay access charges.

Mississippi and Alabama have taken more than just a few steps down the road to New Jerseyization. The medium-rise buildings snuggled up to the beach, missing sand dunes, houses at the high-water mark, and various erosion protective devices are but a few signs of the trend. But encouraging signs also are present. Two of them are the establishment of the original Alabama Coastal Area Board, whose functions have been incorporated into the Office of State Planning and the new Department of Environmental Management, and the Mississippi Coastal Program under the Marine Resource Council and Bureau of Marine Resources. Also, some planners and public officials have realized that seawalls and groins are not satisfactory long-range solutions to the problem of coastal erosion.

Practical advice

Development will continue on the Gulf Coast. It would be unrealistic to expect it to stop. If we are to avoid the mistakes that have been made elsewhere, however, it must be done intelligently. The purpose of this book is to provide Gulf and Bay residents and property owners with the information they need to make intelligent decisions about coastal development. Thus, after giving the brief history of development and storms along the Alabama-Mississippi coast that closes this chapter, we will outline the natural processes that are at work at the shore (chapter 2) and the various ways that people have tried to control these processes (chapter 3). We will then present information about how to evaluate a possible development site, including a segment-by-segment analysis of the Alabama-Mississippi coast (chapter 4). We also will go over the federal, state, and local laws that apply to land use in the coastal zone (chapter 5). Finally, we will discuss the ways that buildings can be constructed to make them safer in a coastal environment (chapter 6). These discussions are supplemented by three appendixes: a hurricane checklist, a guide to government agencies involved in coastal development, and an annotated list of useful references.

The foundations of development: historical perspective

Legends aside, the first known European to explore this coast was the Portuguese Gaspar Cortereal shortly before 1500. A published map is evidence of his discovery. The Spanish followed closely thereafter, particularly in the eastern part of the Gulf. Mobile Bay appears on a 1507 map, and the Spanish explorer Piñeda probably sailed into the bay in 1519. The Spanish claimed what is now Alabama and continued their exploration. Hernando de Soto's famous trek from 1539 to 1542 took him from West Florida into the interior of Alabama and Mississippi, to the discovery of the great river, and ultimately to his death.

In 1558 the Spanish attempted to establish a settlement either on the eastern shore of Mobile Bay or in the Pensacola region. On August 19 of that year the settlers' fleet was struck by a hurricane (reference 1, appendix C). Most of their ships were sunk or blown ashore. It was a poor start, and the attempt at colonization failed 3 years later.

The French were more successful more than a century later. Robert Cavelier de La Salle sailed down the Mississippi River to its mouth in 1682, and in 1688 Henri de Tonti explored the Gulf. In 1699 the first French settlement was established. After exploring the land adjacent to the mouth of Mobile Bay including Dauphin Island, Pierre LeMoyne d'Iberville sailed on to Biloxi Bay where he established a fort and settlers as far west as the Bay St. Louis area. Three years later he moved his settlement to what is now Mobile. During this time Dauphin Island was the principal anchorage for French ships coming to Mobile. However, over the years sand accumulated in the island's harbor, rendering it useless. So the French moved their capital back to old Biloxi in 1719, and Ship Island became the new anchorage. Nevertheless, French development centered on Mobile and on New Orleans in particular. The intervening coast remained wild or with subsistence settlements.

In 1763 Mobile and the Gulf Coast between the Mississippi River and Spanish Florida passed into English control. Coastal development still did not flourish, but British efforts to regain its foothold after losing the Revolutionary War led to the fortification of Mobile Point in 1813. It was the military significance of coastal positions at bay and sound entrances that continued to spur occupation of the barrier islands through the nineteenth century (for example, Fort Pickens at the entrance to Florida's Pensacola Bay and related batteries on Perdido Key, Fort Morgan, and Fort Gaines at the mouth of Mobile Bay, and Fort Massachusetts on Ship Island). From Bay St. Louis to Pascagoula the mainland shore began to see "summer home" development in the period beginning in the 1830s. Growth accelerated after the War Between the States, and by the turn of the century the Mississippi coast was coming to national attention as a resort. Hurricanes were having an impact on the coast as well, and Mississippi's urbanizing shore was moving in a pattern similar to that of New Jersey.

The New Jerseyization phase of the Mississippi shore began as early as 1915 and continued in the 1920s when the first seawalls were constructed. Of 75 miles of shoreline, approximately 40 miles of seawall now exists, fronting extensive residential and commercial development. Much of this shoreline is faced with an artificial beach; a beach from which material still erodes (for example, a recession of from 50 feet to 160 feet was noted between 1951 and 1965 [reference 15, appendix C]). Periodic renourishment is necessary. Armoring the city of Mobile's shore also dates back to the earlier part of this century.

The rapid growth of port facilities, military installations, and commercial/industrial development from the 1940s and beyond led to the urbanization of the Bay St. Louis to Biloxi shore, the Pascagoula waterfront, as well as an enlarging area around Mobile. Bridges, causeways, and road improvements led to the rapid development of communities such as Dauphin Island, Gulf Shores and vicinity, and along some of the bay fronts. Although Alabama generally does not have the massive seawalls and artificial beaches of Mississippi, the New Jerseyization trend is under way in areas such as the east shore of Mobile Bay (Baldwin County) where a single row of cottages sits on low ground behind a nearly continuous set of revetments, groins, with little or no beach, and, similarly, along some of the bay front of Mobile County.

The rapid flood of population to the coast into developments old and new is setting the table for disaster.

Guess who came to dinner?

Frederic and Camille! Unlike the friendly couple next door, these 2 giants came uninvited and unanticipated. Born in the equatorial Atlantic and suckled on seawater, the hurricanes came to the Gulf Coast with an appetite for solid sand. Their appetite knew no barrier as storm surge and waves chewed into barrier islands and the coastal plain shore of Alabama and Mississippi. The bones spit out in the wake of this pair included skeletal remains of cottages, stores and motels, trees and telephone poles, boats and cars, sewer pipes, roads, and causeways. The final tally of the destruction is recorded in the record book (table 1.1); the two costliest storms ever to visit America's shore—more than $3.7 billion total! Storm warnings and preplanned evacuation procedures kept the death tolls down, but 8 died in Frederic, and Camille claimed 256 souls.

Two of the worst storms in history coming only 10 years apart ought to raise a great deal of concern on the part of coastal residents. Such concern should raise some fundamental questions: Were these hurricanes rare and unusual events? Could their record of destruction have been prevented or at least minimized? And, as in the case of the customer who eats and runs, who should be responsible for paying the storm's tab?

The remainder of this chapter addresses the first question, while the focus of the entire book is on the second question. The individual property owner can select site and structure with an eye to safety. The question of "who pays" requires collective action on the part of society, but it is concisely addressed in chapter 5.

Hurricane history: the lesson of the past

From the earliest days of settlement, hurricanes have been the scourge of the Gulf Coast. A storm that struck on September 19, 1559, was a harbinger of winds and waves to come as it destroyed a Spanish fleet anchored in Pensacola Bay. Prior to the eighteenth century no permanent settlements were located on the Alabama-Mississippi coast, so the early record of storms is sparse. Beginning in the early 1700s, settlements were established near the coast and became the recorders of storm events. In September of 1711 a hurricane destroyed the cathedral in New Orleans and moved on to strike Mobile, a city only a decade old. Because of damage inflicted by the storm and associated flooding, Mobile was relocated to its present site—a convenient port but not out of danger from hurricanes.

In the past 270 years the Alabama-Mississippi coast was affected in varying degrees by more than 80 hurricanes. The figures vary from one report to another, but on the average this coast is affected by a tropical disturbance once every 2.5 years. Of these, hurricane-strength storms occur every 3.6 to 4.7 years. For individual sites the average frequency is about 1 hurricane every 8 years. Such average figures are misleading. At least 3 times in the last 2 cen-

Table 1.1. Damage data for Hurricane Camille (1969) in Mississippi (estimated total damage in excess of $1 billion)

Subject	Counties						Regional totals
	Hancock	Harrison	Jackson	George	Pearl River	Stone	
Persons dead	12	114	4	0	0	0	130
Persons injured	2,095	2,110	76	0	37	1	4,319
Persons hospitalized	20	234	56	0	13	0	323
Dwellings destroyed	602	3,075	118	0	29	9	3,833
Dwellings with major damage	1,775	8,493	482	6	520	15	11,291
Dwellings with minor damage	1,496	19,132	1,089	14	2,039	350	24,120
Mobile homes destroyed	162	116	66	0	25	7	376
Mobile homes with major damage	0	206	40	3	33	8	290
Farm buildings destroyed	42	22	40	14	81	49	248
Farm buildings with major damage	81	60	49	27	132	400	749
Small businesses destroyed or with major damage	151	210	60	0	110	2	533
Total families suffering loss	4,375	45,000	2,900	24	3,100	—	55,409

Source: State of Mississippi, *The Mississippi Gulf Coast Comprehensive Development after Camille* (1970). See reference 82, appendix C.

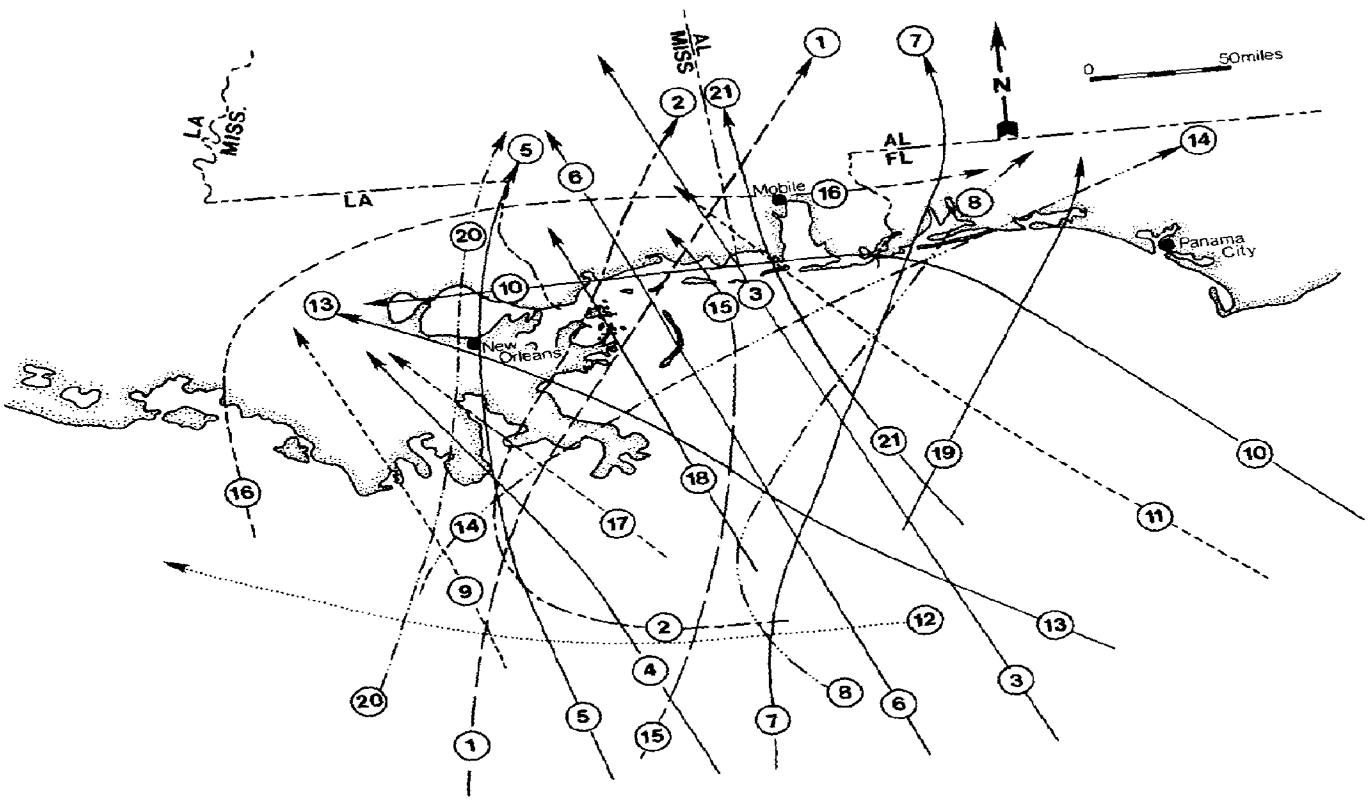
turies as many as 3 hurricanes have struck the Alabama-Mississippi coast in a single year, and within a 2-month span. The occurrence of 6 hurricanes in a 10-year interval has not been uncommon. Seven major hurricanes struck between 1900 and 1980.

The conclusion that must be drawn is that any given structure on the coast will experience a major hurricane in its expected lifetime—perhaps several hurricanes. When taking out a 25-year mortgage to build or buy in a high-hazard zone, one should pause at length to consider hurricane history.

How would modern developments hold up under the onslaught of 2 hurricanes within 1 week as occurred in 1740? The "Twin Mobile Hurricanes" of 1740 eroded away half of Dauphin Island, blew down houses in Mobile, and carried destruction inland. Mobile and the coast from the Mississippi Delta eastward were hit hard again in 1772. The Bay St. Louis Hurricane in 1819 brought widespread destruction along the coast, including casualties. The shores of Mobile Bay were flooded, and Mobile streets were awash with everything from ships to turtles and alligators! The same areas were struck again in 1821 by a storm that caused deaths, property destruction, and shoreline erosion. Both states were affected by hurricanes in 1831 and 1837; Pascagoula was heavily damaged in the latter. The Great Mobile Hurricane of August 1852 was one of the costliest storms up to that time, and repairs and reconstruction were barely complete when another hurricane struck on September 15, 1855, and raked the Mississippi coast from Bay St. Louis to Biloxi. In 1860 3 severe hurricanes struck the Gulf Coast between August 11 and October 2! And so it continued throughout the nineteenth century. At least 15 storms affected the area from 1838 to 1893, culminating in the October 1893 hurricane that made its landfall near Pascagoula. The 1893 storm left 2,000 dead in Louisiana, Mississippi, and Alabama. In some small waterfront communities nearly all of the inhabitants died; the greatest number of casualties were found on Grand Isle, Louisiana. A wall of water 20 feet high swept away the village, the sand spit on which it stood, and 1,650 of the 1,800 inhabitants! The high dollar losses along the coast paled in view of the death toll.

The twentieth century has seen a continuation of this stormy past. Biloxi (1901), Pascagoula-Mobile (1906), Pass Christian-Pascagoula (1909) were costly openers. The September 1915 hurricane caused $13 million in damages and 275 deaths in Louisiana and Mississippi. The loss of more than half the beach road (U.S. 90) along the Mississippi coast prompted action toward the development of the continuous seawall seen today; this in spite of the fact that the same storm demonstrated in Bay St. Louis that seawalls are vulnerable. Less than a year later a lesser storm caused another $200,000 in damages to the same communities. Although the storms of 1916, 1917, 1919, 1920, 1923, 1926 (2), 1932, and 1940 (figs. 1.4, 1.5, and 1.6) were not as destructive as the 1915 storm or storms that were to come, they caused considerable damage along the Mississippi-Alabama coast.

Fig. 1.4. Typical northeastern gulf hurricane tracks for the past century. (Not all storms from this time period are shown. MH indicates a major hurricane.) 1. October 2, 1893, MH; 2. August 15, 1901; 3. September 27, 1906, MH; 4. September 20, 1909, MH; 5. September 29, 1915, MH; 6. July 5, 1916, MH; 7. October 18, 1916, MH; 8. September 28, 1917; 9. September 21, 1920; 10. September 21, 1926, MH; 11. August 31, 1932; 12. August 6, 1940; 13. September 19, 1947, MH; 14. September 24, 1956 (Flossy); 15. September 15, 1960 (Ethel); 16. October 3, 1964 (Hilda); 17. September 9, 1965 (Betsy); 18. August 17, 1969 (Camille), MH; 19. September 23, 1975 (Eloise), MH; 20. July 11, 1979 (Bob); 21. September 12, 1979 (Frederic), MH. Modified from *Report on Hurricane Survey of Mississippi Coast*, by the U.S. Army Corps of Engineers, ref. 15, appendix C.


LA
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Panama City

Fig 1.5. Destruction along the Mobile waterfront after the 1916 hurricane. Photograph courtesy of the Erik Overby/Mobile Library Collection and the University of South Alabama Archives.

Fig 1.6. Flooding along foot of Government Street, Mobile, after the 1916 hurricane. Photograph courtesy of the Erik Overby/Mobile Library Collection and the University of South Alabama Archives.

In September 1947 Mississippi was hit by the most destructive hurricane up to that time. The tide at Bay St. Louis reached a level of 15.2 feet, 3 feet above the maximum level expected once in 100 years. Note that the 1-in-100-year level has been exceeded twice in this century! The storm's associated flood, waves, and wind killed 22 and caused $17.5 million in damage in Mississippi alone, $3.4 million being damage in Biloxi. A U.S. Army Corps of Engineers report (reference 15, appendix C) estimates that Biloxi's damage from a 1947-like storm in terms of 1965 dollars would have been $16 million, and we could guess that it would be several times more by the inflated standards of the 1980s. The damage was high because once again the seawalls were topped or washed out, and flooding also came from back bay areas (figs 1.7 and 1.8).

Some good resulted from the 1947 storm because the Southern Building Code was adopted with added restrictions on constructing temporary buildings that disintegrate into storm debris. The

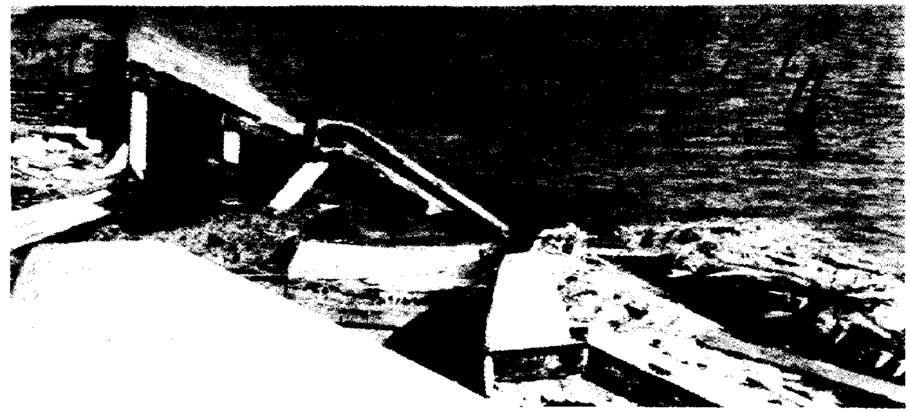


Fig 1.7. The hurricane of 1947 destroyed the Harrison County, Mississippi, seawall.

Fig 1.8. Damage to building behind seawall due to the 1947 hurricane, Harrison County, Mississippi. Photograph provided by the U.S. Army Corps of Engineers, Mobile District, from *Report on Hurricane Survey of Mississippi Coast* (reference 15, appendix C).

storm, however, was the catalyst for adopting a shoreline stabilization philosophy. The seawalls of the 1920s, built in response to the 1915 storm, were now reinforced with an artificial beach as a response to the 1947 storm. A false sense of security was preserved, and the shoreline was redeveloped. This prelude and the relatively hurricane-free period from 1948 through the early 1960s set the stage for Camille in Mississippi, and similarly Frederic in Alabama. Weak and/or offshore hurricanes Baker (1950), Ethel (1960), and Hilda (1964) did nothing to break this false sense of security. Even Betsy (1965) had little effect on the development trend.

Hurricane Camille (1969) was 1 of the 2 Class 5 hurricanes (the strongest recorded) to strike the Gulf Coast in this century (figs 1.9 and 1.10). That storm is one of the reasons this book and companion volumes in the series were written.

Orrin Pilkey, Sr., and his wife lived in Waveland, Mississippi. Their home was at an elevation of 13 feet above sea level, but at the peak of Hurricane Camille the interior of the house was flooded by water 5 feet deep. As the floodwater surged through the house, nearby trees crashed into the roof. In reflecting on their loss, and

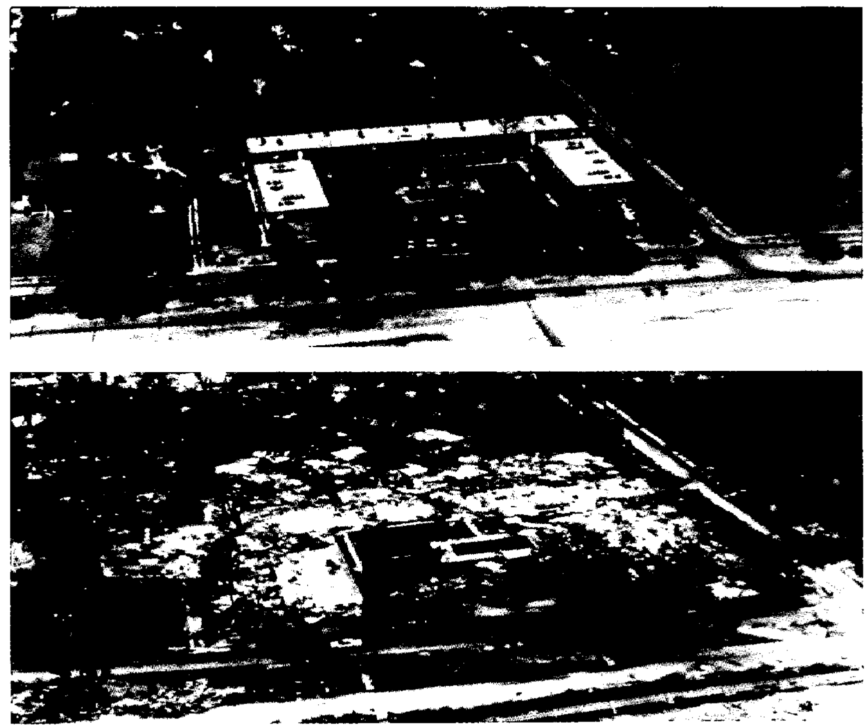


Fig 1.9. Hurricane Camille of August 1969 flattened the three-story Richelieu Apartments in Pass Christian, Mississippi. This pair of "before" and "after" views demonstrate the widespread destruction of the storm. Twenty of the 23 persons who chose not to evacuate the apartment building died in the storm. Photographs provided by the U.S. Army Corps of Engineers, Mobile District, from *Hurricane Camille 14–22 August 1969* (reference 16, appendix C).

the post-storm cleanup, the Pilkeys' experience led to their involvement in trying to communicate the need for prudent coastal development.

The record is clear. Hurricanes are not rare and unusual events. Frederic and Camille were coming and could have been met with more preparation. Development since those storms is following the same imprudent path, because more dangerous storm visitors are on their way. The best agent to depend on in minimizing the effects of these future events is yourself. You can do this through selection of low-risk sites, good construction practices, prestorm emergency preparation, and by heeding storm warnings.

Fig 1.10. The eastbound lane of U.S. Highway 90 immediately behind the seawall at Pass Christian, Mississippi, was destroyed during Hurricane Camille. Photographs provided by the U.S. Army Corps of Engineers, Mobile District, from *Hurricane Camille 14–22 August 1969* (reference 16, appendix C).

Hurricane origin: blow, blow, blow the man down

Each year on June 1 the official hurricane season begins. For the next 6 months conditions favorable to hurricane formation can develop over the tropical to subtropical waters of the Western Hemisphere. Hurricanes that ultimately strike the eastern United States sometimes originate in the Gulf of Mexico or Caribbean Sea early in the season but are more likely to form in the eastern Atlantic Ocean during August, September, and October. Although meteorologists are still seeking answers to the causes and behavior of hurricanes, the basic model is fairly well understood.

During the summer the surface waters off west Africa heat up to at least 79° F. Evaporation produces a layer of warm, moist air over the ocean. This moist air layer is trapped by warm, dry air coming off the African continent, but some of it is drawn upward. As the moist air rises, it cools and condenses, releasing its stored heat (latent heat of vaporization), which in turn warms the surrounding air, causing it to rise. As a result of the increasing mass of rising air, a low pressure area forms (tropical depression) and warm, easterly winds rush in to replace the rising air. The effect of the earth's rotation (Coriolis) deflects the air flow, and a counterclockwise rotating air mass begins to take on the familiar shape of a hurricane. Air forced to the middle of the spiral can only move upward producing a chimneylike column of rising air—the "eye" of the storm.

This heat-engine effect evolves with rising moist air cooling/condensing/releasing heat to cause more air to rise. Lower air rushes in to replace rising air, and the sea provides an endless moisture surface. Heavy rainfall characterizes the edges of the cloud mass, and when sustained wind velocities reach 74 mph the storm is classed as a hurricane. The strongest winds of a hurricane may exceed 200 mph, but the maximum winds of the largest storms to hit coastal areas are rarely recorded because wind-measuring instruments are destroyed or blown away! Frederic's winds reached 160 mph, at sea, and blew at 145 mph in the Dauphin Island area, but Camille came ashore as one of the most intense hurricanes ever with devastating 190 mph winds. Considering that the diameter of a hurricane ranges from 60 to 1,000 miles, and that gale-force winds may extend over most of this area, the total energy released over the thousands of square miles covered by the storm is almost beyond comprehension. No ship or seawall, cottage, condominium, or other static structure will be immune from the impact of such forces!

Hurricane forces: the triple punch

Once a hurricane forms, it begins to move north-northwest, tracking up the Atlantic sometimes into the Caribbean and the Gulf of Mexico. At first the movement is slow, but the speed increases as the storm moves northward, sometimes in excess of 60 mph. If the hurricane makes a landfall, the coast will be subjected to 3 forces, namely high winds, storm surge, and wind-driven waves. In addition, tornadoes may be spawned.

When a storm makes its landfall, the greatest wind velocities will be to the right of the eye when viewed in the direction of the storm migration (northward for the Gulf Coast). The counterclockwise air flow around the eye will produce onshore winds over a stretch of several tens of miles east of the eye's landfall for the Alabama-Mississippi coast. Not only is this area subject to the most intense winds, but also maximum flooding and wave activity. If you find yourself in an area east of the predicted landfall . . . all the more reason to evacuate early! The best precaution, however, is early evacuation regardless of your position. If you are in a low area, a poorly constructed house, or a mobile home, leave for designated shelter at the *first* warning.

Storm surge is a rise in sea level above the normal water level during a storm. Storm surge develops off the coast over deep water where low pressure in the center of the storm causes the surface of the sea to bulge upward. A second phenomenon occurs simultaneously: the counterclockwise swirl of the hurricane winds induces a similar swirling in the water column; this water swirl eventually may extend downward to depths as great as 300 feet. The highest wind speeds are to the right of the hurricane's path—

to the east if the hurricane is traveling north; hence, the maximum water swirl is also to the right of the storm's path. In a typical storm the maximum wind speed and water swirl will occur about 15 miles to the right of the track, placing this area in most danger from storm surge.

As the hurricane approaches land and the water becomes shallower, the swirling water scrapes bottom and begins to build up in a mound to a height considerably above sea level. At the coastline, storm surge may reach a height of 15 to 20 feet or more above sea level. During Hurricane Camille the surge rose to 25 feet above mean sea level in some locations! In most hurricanes inundation of the coastal zone by storm surge and the accompanying storm waves causes the most property damage and loss of life.

Often the pressure of the wind backs water into streams or estuaries already swollen from the exceptional rainfall brought by the hurricane. Water is piled into the lagoons. When the storm moves inland, the water in the bays and lagoons suddenly flows back seaward much faster than it entered. The result is that a house may be flooded from the bay or lagoon side. This flooding is particularly dangerous when the wind pressure keeps the intide from running back out from tide-water rivers, so that the next normal high tide can push the accumulated waters back—and higher still.

The culprit expending energy to destroy structures is the storm wave. Wind-generated, coming on top of the storm-surge flood level, waves right at the shoreline may add another 10 feet to the water's height! The waves erode away protective dunes, strip vegetation, smash buildings, and scour around pilings and protective structures, sometimes undermining them to generate collapse. Debris accumulates to become battering rams and missiles in the next set of waves.

Ranking hurricanes: the Saffir-Simpson Hurricane Scale

Hurricane chroniclers note that many historical accounts characterize each major storm as "the worst ever" or "greater than" the previous "worst" storm. Although storm activity may be cyclic, it is doubtful that storms have increased in intensity. We might conclude erroneously that Hurricane Betsy (1965) and Hurricane Camille (1969) were of equal strength because each storm caused damages totaling $1.4 billion. In reality, Hurricane Betsy was a weaker storm, but it struck more well-developed areas. As coastal development has increased, storm damage has increased accordingly. Similarly, loss of life cannot be used to measure storm intensity or as a comparative measure between storms. Relatively small storms of a century ago were more deadly because they came without warning; there was no time to evacuate. This is why 6,000 people died in the 1900 Galveston, Texas, hurricane. Today, advance warning, efficient evacuation, and safer construction should result in low casualty rates even in a major hurricane. But unsafe development, allowing population growth to exceed the capacity for safe evacuation, and complacency on the part of coastal residents could reverse this trend with shocking results. The National Hurricane Center has warned repeatedly that tens of thousands of Americans could die (and probably will) if a major storm

Table 1.2. *Saffir-Simpson Hurricane Scale*

Category	Winds (mph)	Storm surge (feet)	Central pressure (inches)	Damage	Example
1	74–95	4–5	≥28.94	minimal	Ethel (1960)
2	96–110	6–8	28.50–28.91	moderate	Hilda (1964)
3	111–130	9–12	27.91–28.47	extensive	Frederic (1979)
4	131–155	13–18	27.17–17.88	extreme	September 19, 1947
5	>155	>18	<27.17	catastrophic	Camille (1969)

strikes certain low-elevation areas of heavy development such as in southern or western Florida.

To better warn coastal residents of the strength or intensity of an impending hurricane, the National Weather Service uses the Saffir-Simpson Scale (table 1.2) to describe storms. The scale is based on 3 storm variables: wind velocity, storm surge, and barometric pressure. Considerable correlation exists between these variables, which when combined with a knowledge of the seabed and coastline of a given area can lead to more accurate and timely forecasting of hurricane impact.

Do not be misled by the scale, however. A hurricane is a hurricane, so the scale is defining how bad is bad. Regardless of whether the hurricane is a category 1 or category 5, when the word comes to evacuate, *do it*. Wind velocity may change or the configuration of the coast may amplify storm-surge level, so the category rank you hear in the news report may change by the time the storm reaches your position. Don't gamble with your life or the lives of others. Go!

2. Shoreline dynamics

If you plan to live on or visit the shores of the Alabama-Mississippi Gulf Coast or associated bays, you should understand the natural processes that are at work there. This knowledge is important because your safety and the well-being of the environment are at stake. Furthermore, structures built on the coast must be able to coexist with natural processes without being destroyed or changing the system so as to cause destruction in another place.

Barrier islands: the line of defense

The Gulf Coast barrier islands have been compared to a line of ships in battle formation. The analogy is a good one because the islands are a line of defense between the open sea and the mainland shore (see fig. 1.1). The islands are a buffer to storm winds and waves, a natural offshore breakwater to absorb energy and blunt the storm's striking edge before it reaches the mainland. Fortunately, Mississippi's barrier islands remain undeveloped, a recreational resource in fair weather, standing in reserve to carry out their protective role during storms. In contrast, development on Dauphin Island and from Fort Morgan Peninsula to Perdido Key is either on modern barrier islands or old islands that have become part of the mainland. Houses, condominiums, and other buildings occupy this changing defensive zone.

The islands exist because of rising sea level. The forces acting on the islands and beaches today are essentially the same as those that created them. To appreciate these forces fully as well as to understand the character of the mainland coast, you should be aware of how the islands were formed.

The origin of barrier islands: where did they come from?

Alabama and Mississippi have barrier islands because of the interaction of rising sea level with a coastal plain indented by river valleys. Approximately 15,000 to 18,000 years ago, when sea level was as much as 200 to 300 feet lower than today, the Gulf shoreline was many miles offshore, on what is now the continental shelf (fig. 2.1). Vast glaciers covered the high latitudes of the world, tying up a great deal of water.

When the ice started melting, the sea began to rise. The rising water flooded the valleys, forming bodies of water called embayments (fig. 2.2; stage 1). If you look at a map of today's shorelines, you can see many such inundated valleys, especially along the Atlantic coast of the United States. Chesapeake Bay and Delaware Bay are two prominent examples. Mobile Bay and the smaller St. Louis Bay, Biloxi Bay, Pascagoula Bay, and Perdido Bay are Gulf Coast examples.

If this were all that occurred, the shoreline today would be jagged. Nature, however, tends to straighten jagged shorelines. Shoreline straightening along the Atlantic Coast was carried out by concentrating shoreline erosion on the headlands between the

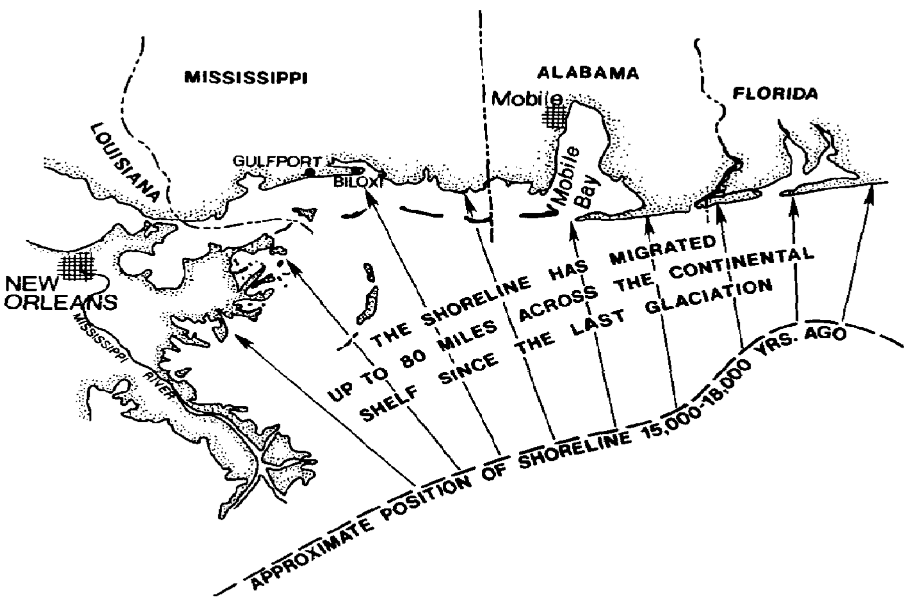


Fig. 2.1. The position of the Gulf shoreline 15,000–18,000 years ago. Sea level was lower because the water was locked up in continental glacial ice caps.

valleys. Wave energy striking the headlands moved sand along the beach by surf zone currents called longshore currents. However, because wave energy, and hence current strength, is greatest at the headlands, the sand being transported could not turn the corner and flow along the estuary (embayment) shoreline. Instead the sand built out from the headlands as spits or sand bars, extending into the bay's mouth (fig. 2.2.; stage 2). The Fort Morgan Peninsula is a similar feature. As sea level continued to rise, the low-lying land behind such spits, plus the sand dunes of the old headland shorelines, then became flooded. The flooding behind the old dune beach complexes resulted in their becoming detached from the mainland, and the barrier islands were born (fig. 2.2; stage 3). This concept of barrier origin and growth was originally put forth by Donald Swift, an imaginative geologist who is now with Arco Oil and Gas Company. It was based on the study of Atlantic seaboard barriers.

Studies by Dr. Ervin Otvos, Jr., of the Gulf Coast Research Laboratory, indicate that the barrier islands fronting Mississippi Sound may have had a different origin. His work, based on drill hole data, past animal life analysis, and the study of historic maps suggests that almost all of the present Mississippi Sound was flooded by the sea no later than 5,000 years ago. Open marine shelf conditions prevailed, but shallow areas (shoals) grew into sand bars and then into islands (reference 22, appendix C). Dr. Otvos concludes that the islands emerged about 3,000 to 4,000 years ago, but since then they have shifted westward in the direction of the prevailing littoral drift (direction of sediment transport

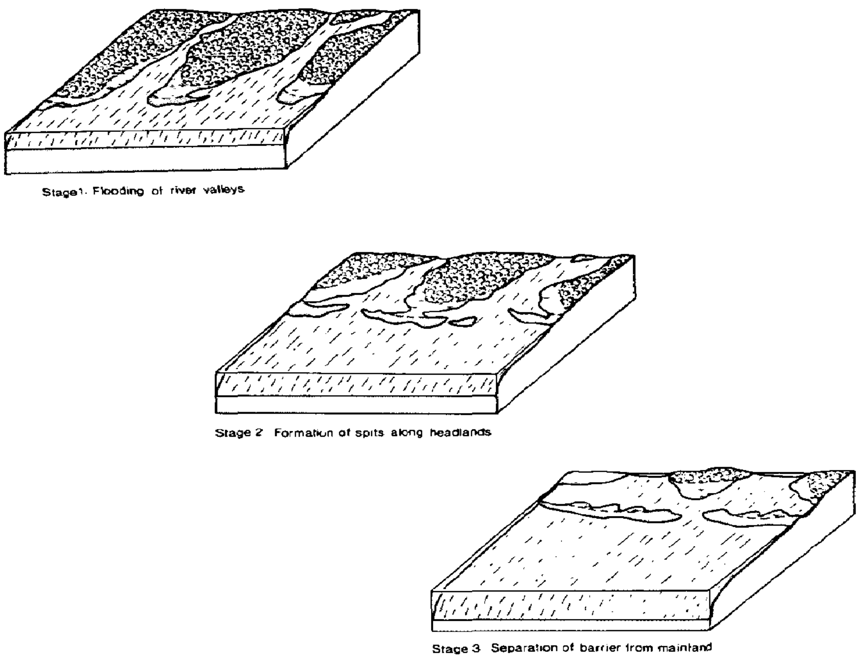


Fig. 2.2. The origin of barrier islands in a rising sea level. Bays develop as river mouths are flooded. Spits form from sand delivered by the erosion of headlands between bays. Spits may become isolated as rising sea level floods land in back of the spits.

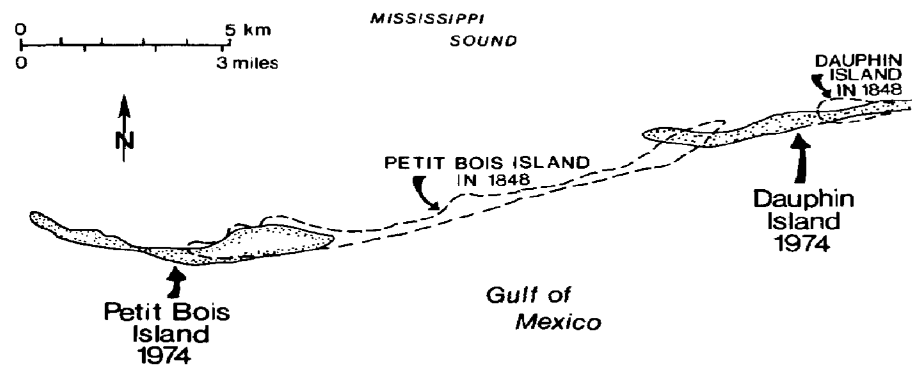
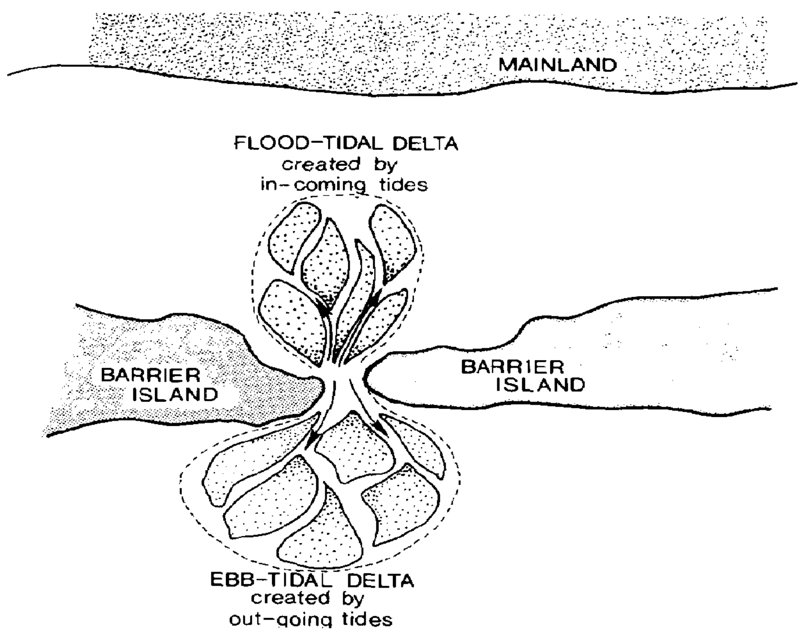


Fig. 2.3. Westward migration of Petit Bois Island and western Dauphin Island in the direction of longshore sand transport.

by waves and nearshore currents; fig. 2.3). Once the islands formed, Mississippi Sound was born and subsequently the Pearl River delta and prograding marshes of the inner sound.

Dauphin Island's origin is a slight modification of this model. The island's eastern end was a large hill at the time of lower sea level. As sea level rose, the hill became an island flanked by shallow water to the west and the tidal delta at the mouth of Mobile Bay to the east. Such tidal deltas are common at inlets and passes between islands (fig. 2.4), or in this case between the Fort Morgan Peninsula and early Dauphin Island. Sand moved westward from the delta along the partly submerged hill to the shallow area where it was deposited as a growing sand bar from east to west, creating

Fig. 2.4. Map showing configuration of tidal deltas that form in front of and behind passes between barrier islands *such as those off the* Mississippi coast. A large ebb-tidal delta exists at the mouth of Mobile Bay between Fort Morgan Peninsula and Dauphin Island.



the low, narrow, elongate island seen today. The sand carried westward along the growing island fed the developing island chain that also migrated westward (fig. 2.3).

The sea-level rise that flooded the Gulf Coast was quite rapid until about 5,000 years ago, at which time it slowed down considerably (fig. 2.5). The slower rate of rise resulted in a somewhat more stable shoreline, although normal shoreline erosion continued. This relative stability, however, appears to have come to an end recently.

The accelerating rise in sea level

Recent studies suggest that in the 1930s the rise in sea level suddenly accelerated (fig. 2.5; inset). Sea level is now rising at a rate of perhaps slightly more than 1 foot per century. Keep in mind that this refers to a vertical rise. The horizontal change—the distance shorelines or islands migrate as a consequence—is much greater (fig. 2.6): between 100 and 1,500 feet per century. How much a specific shoreline moves depends on the slope of its migration surface; the gentler the slope, the farther it will migrate. Subsidence (sinking) of deltas and marshlands adds to this sea-level rise effect so that for some parts of the Gulf Coast the rate of shoreline migration may be even greater.

The safest assumption you can make about the future of the sea-level rise is that it will continue and accelerate. The National Academy of Science and the U.S. Environmental Protection Agency have warned that all evidence points to a warming of the

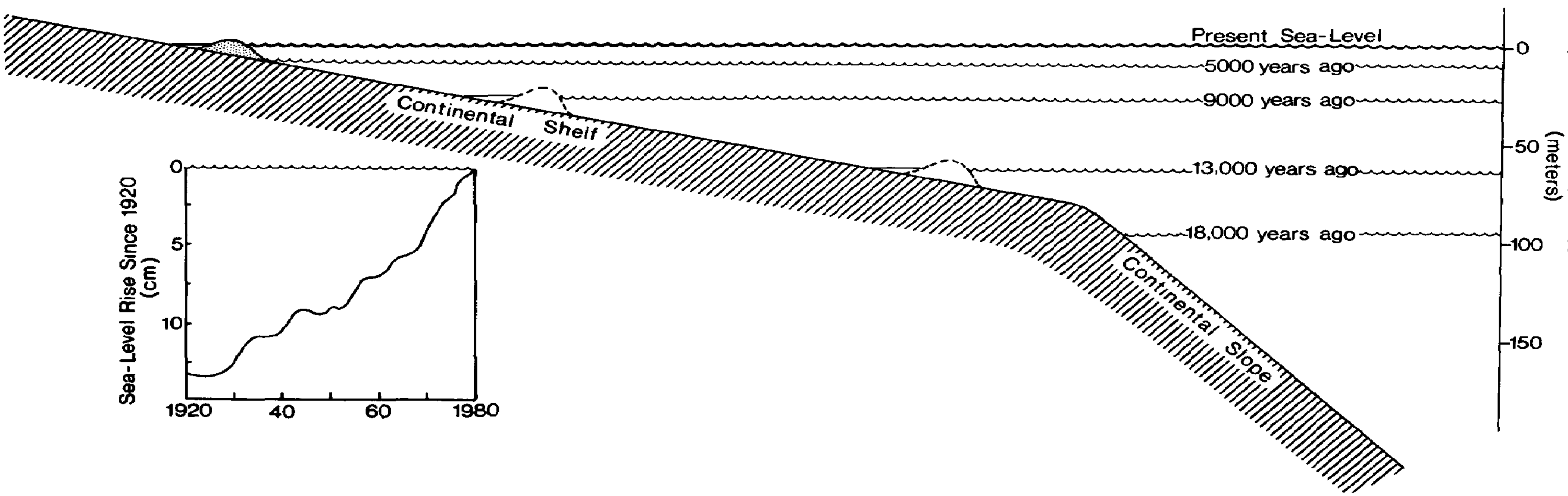


Fig. 2.5. The sea-level rise and flooding of the continental shelf during the past 18,000 years. The inset shows the sea-level rise since 1920.

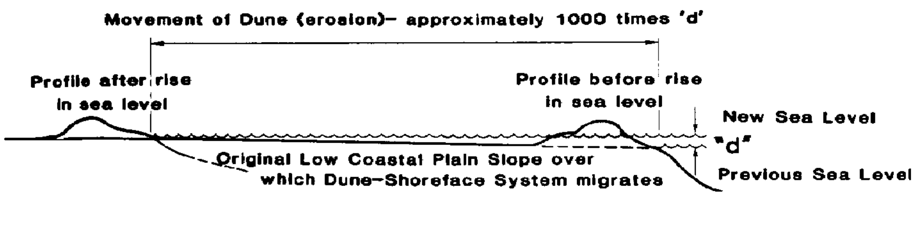


Fig. 2.6. Ratio of horizontal shoreline migration to the vertical sea-level rise. For low-lying coastal areas, a small vertical rise can cause significant horizontal migration.

earth's surface. The burning of fossil fuels has resulted in the excessive production of carbon dioxide, which causes the atmosphere to retain heat. This warming is expected to increase the melting of the polar ice caps, which in turn will raise sea level.

The mainland shore: keeping step with the sea-level rise

For the islands to have remained as islands, the mainland shoreline also must have retreated. If you have not guessed already, *island migration* and *shoreline migration* are the terms that coastal scientists use for what beach cottage owners call "beach erosion."

Although the barrier islands provide a line of defense against the biggest storm waves, Mississippi Sound and Mobile Bay are large enough bodies of water to allow strong waves to form. Not only are low-lying areas flooded by the rising sea level, but the shoreline retreats as a result of wave erosion. Stumps in the surf zone, trees surrounded by beach with their roots in the water, scarps and bluffs carved at the back of the beach, and exposures of old swamp peats along the shore attest to this erosion.

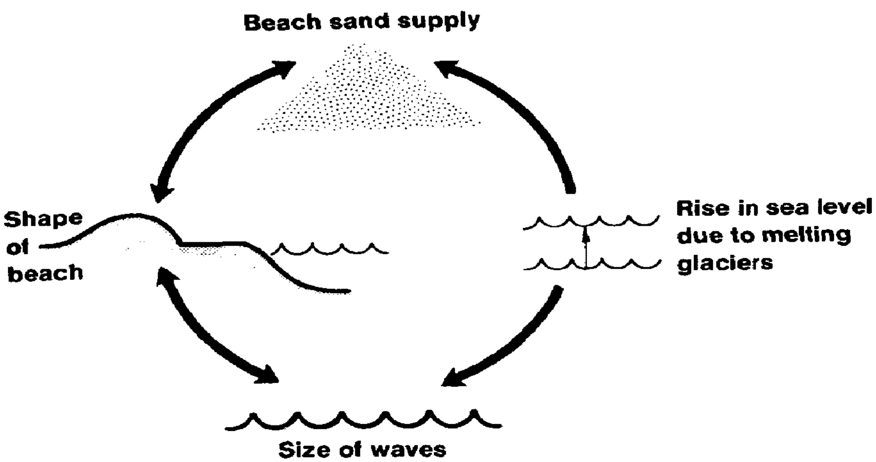
From the Florida Panhandle to the Fort Morgan Peninsula the mainland coast fronts the sea without any offshore island protection. This stretch of shoreline behaves much like a barrier island because of the bays, sounds, and lagoons that make up the area. It is very susceptible to the hazards of coastal processes. Only the beach dune system provides protection.

Beaches: the shock absorbers

The beach is one of the earth's most dynamic environments. This zone of active sand movement is ever-changing and ever-migrating, and these changes are in accordance with the earth's natural laws. The natural laws of the beach control a logical environment that builds up when the weather is good and strategically (but only temporarily) retreats when confronted by big storm waves. This system depends on 4 factors: size of waves, sea-level rise, beach sand supply, and the shape of the beach (fig. 2.7). The relationship among these factors is a natural balance referred to as a "dynamic equilibrium": when one factor changes, the others adjust accordingly to maintain a balance. When human beings enter the system incorrectly—as they often do—the dynamic equilibrium continues to function in a predictable way, but in a way that is harmful to human structures.

Answers to the following often-asked questions about beaches may clarify the nature of this dynamic equilibrium. It is important to keep in mind that the beach extends from the base of the dune to an offshore depth of as much as 30 to 40 feet. It is the zone of sand movement during storms. The part on which we walk is only the upper beach.

Fig. 2.7. The dynamic equilibrium of the beach.



How does the beach respond to a storm?

Old-timers and storm survivors have frequently commented on how beautiful, flat, and broad the beach is after a storm. The flat beach can be explained in terms of the dynamic equilibrium; as wave energy increases, materials move to change the shape of the beach. The reason for this storm response is logical. The beach flattens itself in order to make storm waves expend their energy over a broader and more level surface. On a steeper surface, storm-wave energy would be expended on a smaller area, causing greater damage.

Sometimes besides simply flattening, a storm beach also will consist of one or more offshore bars. The bars serve the function of "tripping" the large waves long before they reach the beach. The sand bar produced by storms is easily visible during calm weather as a line of surf a few to tens of yards off the beach. Geologists refer to the bar as a *ridge* and the intervening trough as a *runnel*.

Figure 2.8 illustrates the way in which the beach flattens. Waves take sand from the upper beach or the first dune and transport it to the lower beach. If a hot dog stand or beach cottage happens to be located on the first dune, it may disappear along with the dune sands.

A great deal of sand may be lost during a storm. Much of it will come back, however, gradually pushed shoreward by fair-weather waves. As the sand returns to the beach, the wind takes over and, if allowed, slowly rebuilds the dunes, storing sand to respond to nature's next storm call. In order for the sand to come back, of

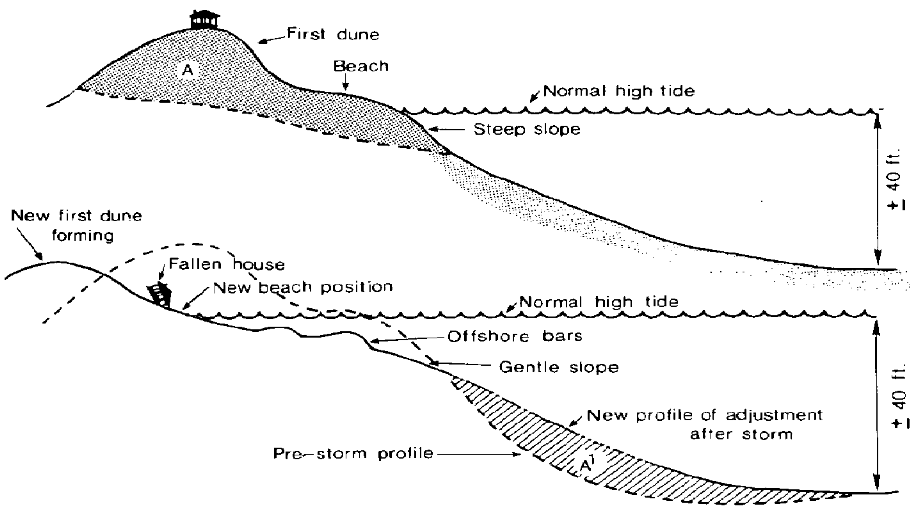


Fig. 2.8. Beach flattening in response to a storm.

course, there should be no man-made obstructions—such as a seawall—between the first dune and the beach. Return of the beach may take months and even years.

How does the beach widen?

Beaches grow seaward in several ways, principally by (1) new sand brought in by the so-called longshore (surf-zone) current, and (2) new sand brought in from offshore by forming a ridge and runnel system. Actually, these 2 ways of beach widening are not mutually exclusive.

Longshore currents are familiar to anyone who has swum in the ocean; they are the reason one sometimes ends up somewhere down the beach, away from one's beach towel. Such currents result from waves approaching the shore at an angle; this causes a portion of the breaking waves' energy to be directed along the beach. When combined with breaking waves, the weak current is capable of carrying large amounts of very coarse material for miles along a beach. Along the Alabama-Mississippi coast the dominant direction of longshore current movement is toward the west. As a result, the eastern ends of the barrier islands are undergoing erosion, while the western ends elongate as sand is deposited. This system accounts for the westward migration of the islands (fig. 2.3). The slightly curved sand bars deposited at the ends of the islands are called *spits*, and similar deposits may occur along mainland coasts, for example, the Fort Morgan Peninsula.

Ridges and runnels (fig. 2.9) formed during small summer storms virtually march onto the shore and are "welded" to the

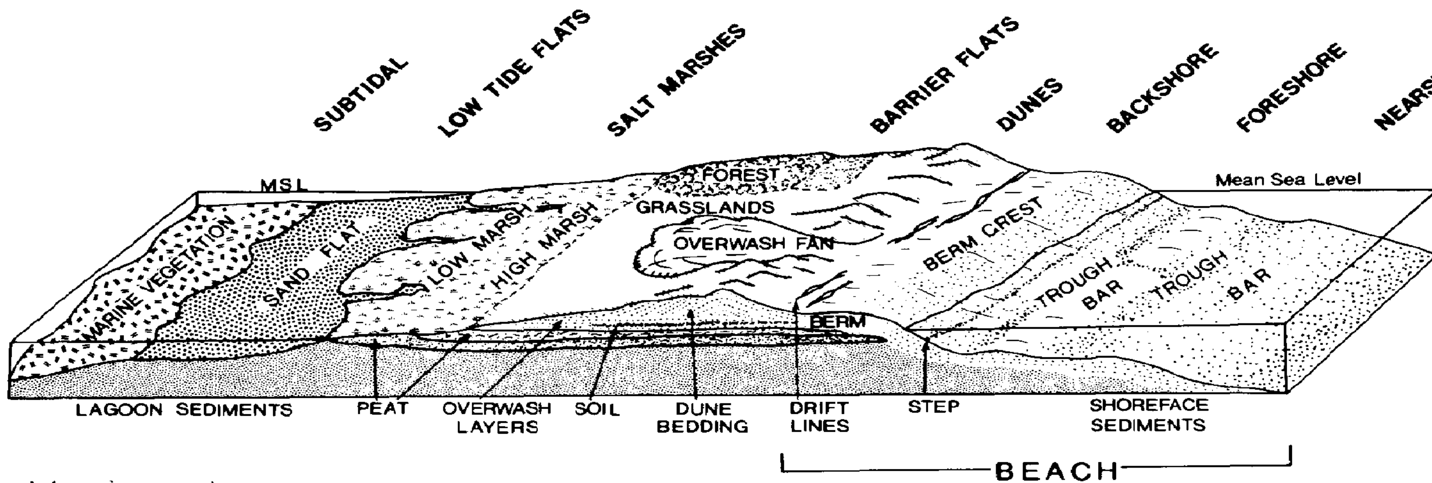


Fig. 2.9. Coastal environments.

beach. The next time you are at the beach, observe the offshore ridge for a period of a few days and verify this for yourself. You may find that each day you have to swim out a slightly shorter distance to stand on the sand bar.

At low tide during the summer the beach frequently has a trough filled or partly filled with water. This trough is formed by the ridge that is in the final stages of welding onto the beach. Several ridges combine to make the *berm*, or beach terrace, on which sunbathers loll.

Where does the beach sand come from?

Along most of the eastern Gulf Coast the sand comes from the adjacent continental shelf. It is pushed up to the beach by fair-weather waves. Additional sand, sometimes in very large quantities, is carried laterally by longshore currents that move in the surf zone parallel to the beach. Lesser amounts of mainland beach sand may be derived from erosion of the land at the back of the beach, producing the scarps or bluffs along eroding shorelines. Sand carried by rivers does not make it to the coast because it is deposited inland at the heads of the estuaries. When sea level was much lower and the rivers flowed onto the present continental shelf, river sands were deposited in the area. This accounts for some of the shelf sand that has been moved landward by waves since the rise in sea level. Broken seashell material is another source of beach sand.

It is important for beach dwellers to know or at least have some feeling for the source of sand for their beach. If, for example, there is a lot of longshore sand transport in front of your favorite beach, it (the beach) may well disappear if someone builds a groin "upstream." Community actions taken on an adjacent beach or inlet potentially could affect your beach, just as your action may affect your coastal neighbors.

Where do seashells come from?

Most shells are the recent remains of animals that lived offshore, or even within the beach. Most will be broken up to produce sand. Surprisingly, some shells from the beach may have radiocarbon ages measured in thousands of years and represent reworked shells, eroded and transported as the shoreline migrated landward.

If you use a shell book to carefully identify specimens from a beach, you may find that bay or lagoon shells are present on the ocean-side beach. As the shoreline migrated landward, it ran over the shells of animals that once lived in back-island or bay environments. In a few hundred or thousand years these shells were reexposed on the ocean-side beach.

Why do beaches erode?

As we have already pointed out, "beach erosion" is the cottage owner's term for the larger process called shoreline migration. Its principal cause is the sea-level rise, presently judged to be about 1 foot per century along most of the American shores. We can be thankful that we do not have the higher rates of nearby Louisiana or of the New England coast. The reason the sea-level rise can be different in different coastal areas is because the land also may be slowly sinking (for example, the Louisiana delta region) or rising relative to sea level.

A geologist once spoke at a luncheon in Virginia Beach, Virginia, and told the audience that the most serious problem facing their eroding shoreline was the rising sea level. A local reporter, mocking the speech, reported that we must "beware the year 4000" for then our houses will be underwater. The joke was on him, for by then his house probably would be 20 miles out to sea as well as in water 30 feet deep! He failed to understand that the impact is within one's lifetime and should not be regarded as such a long-term event as to be of no consequence.

The real problem is not the vertical sea-level rise, but rather the horizontal retreat of the shoreline caused by the rise (fig. 2.6). As you remember, the sea level has been going up and down several hundred feet over the last million years because of the advance and retreat of glaciers in the higher latitudes. As the sea level rises, nature does not make things hard on herself by constructing a giant sand ridge or some other such feature to hold back the sea. On the contrary, the shoreline smoothly moves back and forth with the changing sea level for tens if not hundreds of miles.

Keep in mind that the sea-level rise causes the water level to rise in the bays, so their shorelines also retreat. In the case of islands and peninsulas, both sides will erode. Sand bluffs and surf-zone stumps are evidence of such erosion.

If most shorelines are eroding, what is the long-range future of beach development?

The long-range future of beach development is a function of how individual shore communities are able to respond to the migration. Those communities who choose to protect their frontside houses at all costs need only look to portions of the New Jersey shore to see the end result. The life span of houses can unquestionably be extended by "stabilizing" a beach (stopping the erosion). The ultimate cost of stopping erosion, however, is loss of the beach. The time required for destruction of the beach is highly variable and depends on the situation. Barrier islands are usually the most sensitive. An extensive barrier island seawall may cause extreme beach destruction in as little as 10 to 30 years. Often a single storm will permanently remove a beach in front of a seawall.

If somehow a community can grit its teeth and buy, move, or let the front row of buildings fall in as their time comes, the beaches can be saved in the long run. Unfortunately, so far in America the primary factor involved in shoreline decisions that every beach community must sooner or later make has been money. Poor communities let the beach roll on. Rich ones attempt to hold it in place.

The future of shoreline development in the United States appears to be one of increasing expenditure of money leading to increasing loss of beach.

What can I do about my eroding beach?

This is a complex question and is partially answered in chapter 3. If you are talking about an open ocean shoreline, there is nothing you can do unless (1) you are wealthy or (2) the U.S. Army Corps of Engineers steps in.

It should be pointed out that the U.S. Army Corps of Engineers in their periodic hurricane study reports has concluded that additional expenditure of funds for engineering structures was not warranted for those portions of Alabama and Mississippi studied.

Your best response, especially from an environmental standpoint, is to move your threatened cottage elsewhere. The bottom line in trying to stop open ocean shoreline erosion is that the methods employed will ultimately increase the erosion rate. For example, the simple act of hiring a friendly local bulldozer operator to push sand up from the lower beach will steepen the profile and cause the beach to erode more rapidly during the next storm. Pumping in new sand (replenishment) costs a great deal of money, and in many cases the artificial beach will disappear much more rapidly than its natural predecessor.

In sum, there are many ways to stop erosion in the short run if lots of money is available; in the long run, however, erosion cannot be halted except at the cost of losing the beach.

The evolution of barrier islands: how they operate

Every barrier island is unique. Each island evolves by mechanisms that may differ slightly or substantially from those of adjacent islands; thus, each island must be understood separately.

For years scientists did not realize this and treated all barriers as if they were the same. Geologists and biologists studying barrier islands in Texas argued with those studying barrier islands in New Jersey. Each group of scientists thought the other group was unobservant. When an investigator attempted to apply what was learned about New Jersey islands to Texas islands, he found the information did not apply, and vice versa. Thus, scientists realized that there are fundamental differences among look-alike barrier islands.

Let us compare Alabama-Mississippi and Texas barrier island systems on a broad scale. If you dam a river in Alabama or Mississippi, it should not affect the state's barrier islands at all because Alabama and Mississippi islands get most of their sand from the adjacent continental shelf. Texas islands, however, are nurtured by rivers such as the Rio Grande and the Brazos that furnish sand directly to the shoreline during every flood. When this supply is stopped by dams, as it partially has been, the beaches begin to "starve" and retreat more rapidly. Another major difference between Texas and Alabama-Mississippi barrier islands is in their response to *overwash*. On Texas barrier islands such as Padre Island, overwash passes—where waves wash sand onto the island—have been flooded again and again during successive storms at the same positions. On Alabama-Mississippi islands the sites of major overwash deposits have shifted through time. During Hurricane Frederic in 1979 much of the western two-thirds of Dauphin Island suffered overwash.

Other natural differences between islands can be due to such things as average grain size of the sand, island orientation relative to the dominant wind direction, variation in sand supply, amount of shells in the sand, amount and type of vegetation, the character of adjacent inlets and tidal deltas, etc. Fine sands retain water better than coarse sands; hence, vegetation will restabilize storm-destroyed dunes more rapidly when the sand is fine. Islands oriented with dominant wind direction up and down the length of the island tend to have poor dune buildup because not much sand is supplied to the island from the beach. Islands with large sand supply tend to be fatter than those with only a small amount of sand coming ashore. High shell content of the sand, typical for many southern U.S. barrier islands, will reduce the amount of sand available for dune construction. Fresh sand that comes ashore during storm washover is winnowed by the wind until a lag layer of coarse shells remains. At that point the wind has a tough time getting additional sand because the shells stabilize the sand much like vegetation does.

The point we emphasize is that each island has a different story to tell. The island dweller must learn and respond to the unique traits of the particular island they inhabit—if they want to preserve it.

Having discussed differences among barrier islands, let us mention some things they have in common. While the major mechanisms by which islands move are the same everywhere, the rates and intensities at which these mechanisms operate differ widely.

In order for an island to migrate, the front (ocean) side must move landward by erosion, and the back (sound) side must do likewise by depositional growth. In other words, one end of the island must lengthen, while the other end erodes. As it moves, the island must somehow maintain its elevation and bulk.

Front side moves back by erosion

The beach moves back because the sea level is rising. This sea-level rise is the main worldwide cause of beach erosion, although other local factors such as the lack of sand supply also may cause the problem. The shoreline of the Nile Delta, for example, is eroding at an unprecedented rate because the Aswan Dam on the Nile River has cut off the supply of new beach sand. Beaches in California are disappearing for the same reason, that is, because of dam construction blocking the flow of river sediment.

As the sea level rises, the sandy coastal plain shoreline retreats. (The mechanism of shoreline retreat was discussed earlier in the chapter, in the section on beaches.) At this point, we need only recognize that the beach retreats horizontally at 100 to 1,000 times the rate of vertical sea-level rise, and that the rate of retreat essentially controls the rate of island migration, as well as mainland shoreline migration.

Back of island moves landward by growth

One way that islands, especially narrow ones, can be widened is by direct frontal *overwash* of storm waves from the ocean side of the island (fig. 2.9). All barrier islands receive overwash during storms. On large ones the overwash may barely penetrate the first dune line. On low, narrow ones overwash may be carried across the island to reach the sound. Overwash waves carry sand that is deposited in tongue-shaped or fan-shaped masses called *overwash fans*. When such fans reach into the sound, the island is widened.

Overwash is the method of backside growth used by islands in a hurry, that is, those that are migrating rapidly landward. Capes Island, South Carolina, and some of Louisiana's islands are examples. Between 15,000 and 25,000 years ago when the sea level was rebounding rapidly, most American barrier islands were probably of the overwash type. Many if not most barrier islands are today eroding on both front and back sides in response to the sea-level rise. Basically the islands are all going through the first stage of converting themselves back to overwash islands so they can respond quickly to the sea-level rise. If the rise continues, a few hundred years from now American barrier islands will be totally unlike their present-day ancestors.

The island maintains its elevation during migration

The remaining problem of a migrating island is how to retain its bulk or elevation as it moves toward or parallel to the mainland. This problem is solved by two processes: dune formation and overwash fan deposition.

Dunes are formed by the wind, and if a sufficiently large supply of sand comes to the beach from the continental shelf via the waves, a high elevation island can be formed (fig. 2.9).

The reasons for the lack of dune formation on islands of low elevation are the lack of sand supply from the adjacent continental shelf or dominant wind direction up and down the beach rather than across it.

Coastal environments: an integrated system

At this point you understand how barrier islands and mainland shorelines develop and operate, and the important principle that each system is unique. Therefore, if you want expert advice, do not ask the old-timer from New Jersey or Texas to evaluate your cottage on the Alabama-Mississippi coast.

Another important concept to understand is that barrier island environments (fig. 2.9) are interrelated. Each environment is part of an overall integrated system and to some degree depends on or affects other environments within the system. Specific environments are discussed in chapter 4.

Perhaps the best example of one environment affecting others in the system is provided by the role of the ocean-side beach. The beach is important because (1) it alters its shape during storms in such a way as to minimize fundamental damage to the shore by waves, and (2) it is the major source of sand for the entire system. Examples of the ways in which man has interfered in the integrated system may best illustrate these functions.

Dr. Paul Godfrey of the University of Massachusetts discovered that the building of the National Park Service's dune-dike system, the long, continuous, artificial dune on the Outer Banks of North Carolina near Cape Hatteras, is causing erosion on the *sound side* of the island. The problem is that the artificial dune prevents overwash fans from crossing the island during storms. Before the dune was built, overwash frequently reached the back side of the island, and new salt marsh was formed on the edge of the new overwash fan. Newly formed *Spartina* marsh is an excellent erosion buffer against sound-side waves. By preventing overwash, the frontal dune on the island's ocean side precludes new marsh growth and increases the sound-side erosion rate.

Coastal forests also illustrate the integration of environments. Large trees form a canopy over the less salt-tolerant undergrowth. The undergrowth in turn stabilizes the larger trees by holding down the soil. If trees are thinned or removed, sea spray can attack and eliminate the undergrowth. Loss of undergrowth vegetation allows sediment to be eroded by wind or other processes, thereby destroying the trees.

Much has been said about the damage to beaches and dunes by dune buggies and other off-road vehicles. This problem further attests to the integration of island environments. Dune buggies can prevent dunes from stabilizing (become stationary), and destabilization (sand movement) may result in destroyed dunes and vegetation or sand dune migration into forests.

The most common cause of excessive sand movement in coastal areas is construction. The problem is particularly acute during the early stages of construction and in many instances has halted further construction altogether. A very common mistake in coastal construction is placing roads in such a way as to ensure that they will someday be overwash passes when a good-sized storm comes by. Along many American beaches you can drive down roads that run parallel to the beach and observe that at the end of each beach feeder road there is a giant notch through the last row or two of dunes. The notch is certain to someday be filled by storm wave overwash and storm-surge floodwaters.

Just as environments on a single island or coast depend on one another, so do environments on adjacent coasts and islands. Beaches are like flowing rivers of sand. Frequently beaches depend on neighboring beaches for sand supply. When the river of sand is cut off by inlet dredging or construction of jetties, groins, or seawalls, the beach erosion rate increases. This raises the question of what actions should be taken to slow down shoreline erosion, and what will be the impact of these "solutions"?

3. Man and the shoreline

As a result of coastal evolution, storm waves, and the general sea-level rise, shoreline recession is a widespread phenomenon. In the past developers may have been unaware of the problem; in recent times some have ignored it. Older development has been lost, and the eroding scarp at the back of the beach threatens structures in its path. The common response to this natural process is usually some method of shoreline stabilization. Note that the word is shoreline—not beach— stabilization. Stabilization means holding in place.

Shoreline engineering: no deposit—no return

Shoreline engineering is a general phrase that refers to methods of changing or altering the natural shoreline system in order to stabilize it. Stabilization methods range from the simple planting of dune grass to the complex construction of large seawalls using draglines, cranes, and bulldozers. Structures may run for miles in front of urbanized shores, or only tens of feet in front of an individual bay lot.

The benefits of these methods are often short-lived and usually cause beach retreat or beach loss in front of the stabilized property or adjacent property. Such is the case, for example, in front of the Bay St. Louis seawall, parts of the Pascagoula seawall, downdrift from the Dauphin Island groin field, and in front of the extensive wooden revetment walls along the eastern shore of Mobile Bay. In some cases beach loss or retreat caused by man may be greater and more spectacular than nature's own.

The economic and environmental price for stabilizing shorelines also is high. Public awareness of the magnitude of the problem is essential before any decisions are made to extend such projects and further burden the taxpayer. There are, of course, a few situations in which stabilization is an economic necessity. Shipping channels leading to our major ports, such as Mobile, Pascagoula, Biloxi, and Gulfport, for example, must be maintained. The continuous stabilization project in front of the urbanized shore from Biloxi to Bay St. Louis cannot be abandoned now. But similar projects can be avoided.

There are 3 major ways by which shorelines are stabilized. These methods are listed below, in decreasing order of environmental safety.

Beach replenishment

If a beach must be repaired, beach replenishment is probably the most gentle approach. Replenishment consists of pumping or trucking sand onto the beach and building up the former dunes and upper beach. Sufficient money is almost never available to replenish the entire beach out to a depth of 30 or 40 feet. Thus, only the upper beach is covered with new sand, so that in effect a steeper beach is created (fig. 3.1). This new steepened profile often increases the rate of erosion. Few studies have been made of this

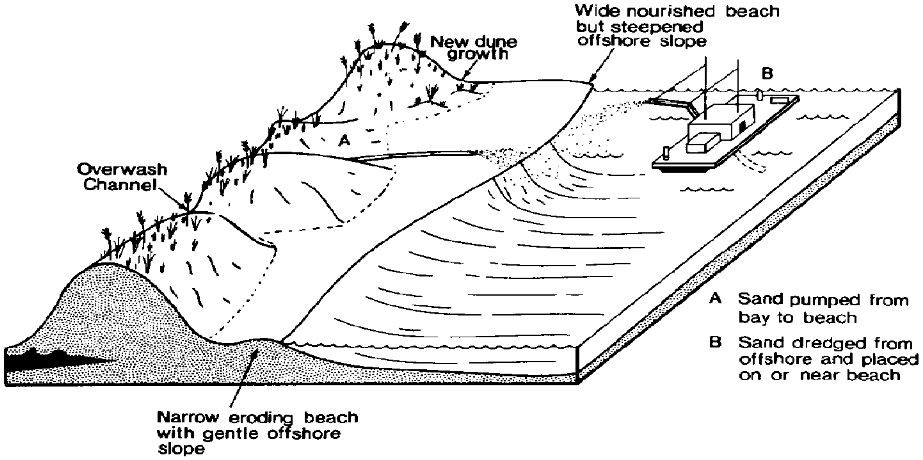


Fig. 3.1. Model of beach nourishment.

phenomenon, but replenished beaches often disappear faster than the natural beaches they replaced. In beach replenishment, sand is either pumped from the adjacent continental shelf, offshore sand bars, barrow pits on the land, or from the adjacent bay or sound. If the replenishment sand is muddy or of a finer size than the original beach sand, it quickly washes off the beach. Dredging can disturb the ecosystem, and the hole created can change the local pattern of waves and currents. In a replenishment project along the Connecticut coast, wave patterns changed by a dredged hole on the shelf quickly caused the replenished beach to disappear. Such holes can also be hazards to waders and swimmers. A dredge hole produced some 1,500 feet offshore near Buccaneer State Park, Waveland, Mississippi, caused at least 25 drownings from 1966 until it was filled in the early 1980s. The pit was produced about a year after Hurricane Betsy when sand was dredged to reconstruct a beach in front of the seawall in Bay St. Louis. The hole had backfilled with a soupy mud, creating a quicksandlike bottom.

A more threatening effect of beach replenishment is that a false sense of security from storm attack is maintained. Value of property behind a nourished beach is maintained or increases, spurring an increase in development—including condominiums. The growth in development density increases the shore community's demand for the next round of beach replenishment. Historically, however, beaches cannot be replenished again and again. Sand supplies become exhausted, more distant, and more costly. Natural sand supply diminishes as the stabilized beach, held in place where we think it "should be," becomes more and more out of equilibrium with the rising sea level. Eventually the coastal community will resort to more drastic stabilization measures such as a seawall. In Harrison County, Mississippi, beach fill was utilized to protect the stepped seawall, which was constructed to protect the shoreline, etc., etc. Recent nearshore construction in Alabama is setting the stage for future demands for beach nourishment, seawalls, groins, and similar structures. The lessons of New Jersey have been lost on a new generation.

The most celebrated beach replenishment of recent years was the $68 million Miami Beach project. Fifteen miles of beach were replaced. On a nationwide basis the cost of beach replenishment is approaching $2 million per mile. Consider the fact that virtually hundreds of miles of American shoreline have buildings crowded close to the beaches. All of these communities will soon be "in danger" from shoreline erosion because sea level is rising. If the majority of these communities seek to stabilize their shorelines, the potential cost to the taxpayer, local and federal, is tremendous. So much so in fact that a taxpayer's rebellion is brewing as reflected by the introduction of barrier island bills in recent sessions of Congress. Such legislation will limit federal expenditures (subsidies) in coastal areas. Future support for beach replenishment most likely will become more and more difficult to obtain.

The Harrison County, Mississippi, beach nourishment project (fig. 3.2) is an example of a modest short-term success. The county's 27-mile Gulf shoreline was beachless in 1950, in part because of the stepped seawall (see later section in this chapter on the effects of seawalls). The entire 27 miles was nourished with more than 7 million cubic yards of sand in 1951. The sand was borrowed

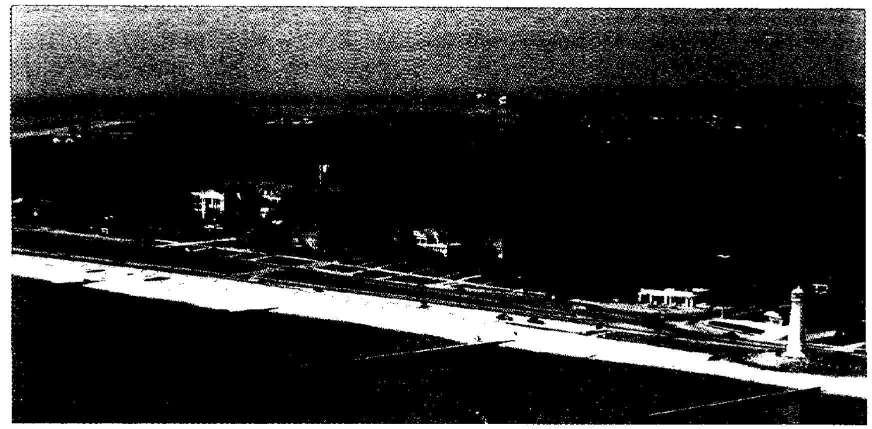


Fig. 3.2. Harrison County's artificial beach at Biloxi (1950s). The beach was built in 1951 to protect the seawall at the back of the beach and must be renourished periodically. Photo provided by U.S. Army Corps of Engineers, Mobile District.

from about 1,500 feet offshore, forming a continuous 14-foot-deep trench parallel to the shoreline. In the first 7 years after the beach construction, a time without major storms, only 15 percent of the fill was lost. By 1972 the loss was approaching 30 percent. Hurricane Camille did not destroy the beach, perhaps because the storm tide rose and receded so fast along this coast. Nevertheless, this long stretch of beach ultimately will require renourishment. Storm conditions like those of the 1940s and earlier hurricanes could eliminate this artificial beach relatively quickly. Some of the lost sediment will be trapped in the original dredge trench, but the question remains, where will future sand supplies come from for beach renourishment?

In summary, beach replenishment upsets the natural system, is costly and temporary, and requires subsequent replenishment projects to remain effective. The Corps of Engineers refers to beach replenishment projects as "ongoing," but the implication is an "eternal" confrontation with nature. Thus, serious economic questions can be raised by the public (taxpayers) when the facts associated with beach nourishment are considered. The expense of such projects and the burden of "perpetual care" with continually recurring costs provide the greatest benefit, not to the general public, but to shorefront property owners whose property they "protect." Cries for beach nourishment projects invariably come from those with direct economic interests associated with beach use, that is, owners of cottages, motels, beachwear and gift shops, and other commercial interests in the community. Many feel that beach nourishment is a form of government subsidy for such interests. Beach visitors, the public who use the beach, rarely clamor for such projects. Beach replenishment, however, may be viewed as the lesser of structural stabilization evils, particularly when compared to the following methods.

Groins and jetties

Groins and jetties are walls built perpendicular to the shoreline. A jetty, often very long (sometimes miles), is intended to keep sand from flowing into a ship channel (for example, Perdido Pass, fig. 3.3). Groins, much smaller walls built on straight stretches of beach away from channels and inlets, are intended to trap sand flowing in the longshore (surf-zone) current. There are groins present along significant stretches of the Mobile Bay shore, on the

Fig. 3.3. Perdido Pass jetties. Photo by Bill Neal.

Fig. 3.4. Groin field on the eastern end of Dauphin Island. Note detached groin, 1981. Photo by Bill Neal.

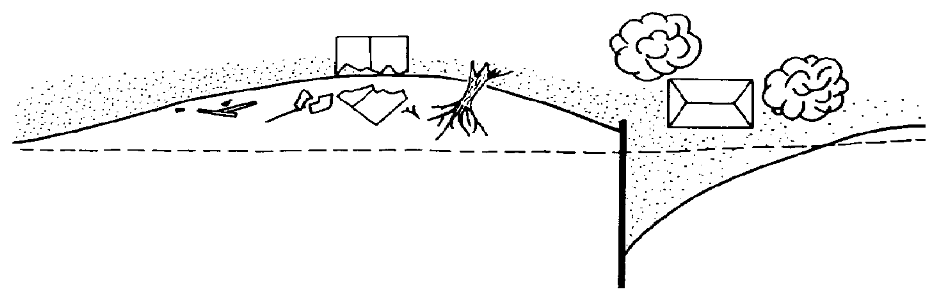
east end of Dauphin Island (fig. 3.4), and along portions of the Mississippi shoreline in combination with seawalls. Groins can be made of wood, stone, concrete, steel, or nylon bags filled with sand.

Stone groins with revetments are also common in areas where beaches and property are threatened. Great Point Clear, eastern Mobile Bay, and Pelican Point on Dauphin Island are good examples.

Both groins and jetties are very successful sand traps. If a groin is working correctly, more sand should be piled up on one side of it than on the other. The problem with the groin is that it traps sand that is flowing to a neighboring beach. Thus, if a groin on one beach is functioning well, it must be causing erosion elsewhere by "starving" another beach (fig. 3.5). The same is true, of course, of jetties. During storms, erosion often detaches the groins from the shore, causing them to be useless as sand traps (fig. 3.4).

Miami Beach illustrates the results of groin use. After one was built, countless others had to be constructed—in self-defense. Prior to the 1977 beach renourishment project, Miami Beach looked like a military obstacle course; groins obstructed both pedestrian and vehicular traffic. Groins and other forms of shoreline engineering destroyed the beach at Miami Beach. Now, only through an eternal commitment to beach renourishment can the artificial beach be maintained.

Fig. 3.5. Model map view of a groined shoreline.



Seawalls

Seawalls, built back from and parallel to the shoreline, are designed to receive the full impact of the sea at least once during a tidal cycle. Present in almost every highly developed coastal area, seawalls are common along most of the developed Mississippi coast (fig. 3.2). Other common structures are bulkheads and revetments. Bulkheads are a type of seawall placed farther from the shoreline in front of the first dune—or what *was* the first dune—and designed to take the impact of storm waves only. Wooden bulkheads are used commonly in bays and estuaries to prevent shoreline erosion. Although less costly than more massive seawalls, bulkheads require maintenance and cannot withstand large storm waves. Revetments are usually stone facings placed on eroding scarps or bluffs to slow storm-wave erosion.

Building a seawall, bulkhead, or revetment is a very drastic measure on the ocean-side beach, harming the environment in the following ways:

1. *It reflects wave energy, ultimately removing the beach and steep*ening the offshore profile. The length of time required for this damage to occur is 1 to 30 years. The steepened offshore profile increases the storm-wave energy striking the shoreline; this in turn increases erosion.
2. It increases the intensity of longshore currents, hastening removal of the beach (fig. 3.6).
3. It prevents the exchange of sand between dunes and beach. Thus, the beach cannot supply new sand to the dunes, nor can the beach flatten as it tends to do during storms.
4. It concentrates wave and current energy at the ends of the wall, increasing erosion at these points.

The emplacement of a seawall or other "hard" structure is an irreversible act with limited benefits. By gradually removing the beach in front of it, every seawall must eventually be replaced with a bigger ("better"), more expensive one, or an artificial beach must be maintained. While a seawall may extend the lives of beachfront structures in normal weather, it cannot protect those on a low-lying coast or barrier island from the havoc wrought by hurricanes; it cannot prevent overwash or storm-surge flooding. In fact, floodwaters may be trapped and held behind such a wall during a storm.

The long-range effect of seawalls can be seen in New Jersey and Miami Beach. In Monmouth Beach, New Jersey, the town building inspector told of the town's seawall history. Pointing to a seawall he said, "There were once houses and even farms in front of that wall. First we built small seawalls and they were destroyed by the storms that seemed to get bigger and bigger. Now we have come to this huge wall which we hope will hold." The wall he spoke of, adjacent to the highway, was high enough to prevent even a glimpse of the sea beyond (fig. 3.7). There was no beach in front of it, but remnants of old seawalls, groins, and bulkheads extended for hundreds of yards to sea.

Beach community residents must be aware of the bottom line when a seawall is constructed. A seawall is an expensive commitment to preservation of shorefront structures only. The beach will be destroyed.

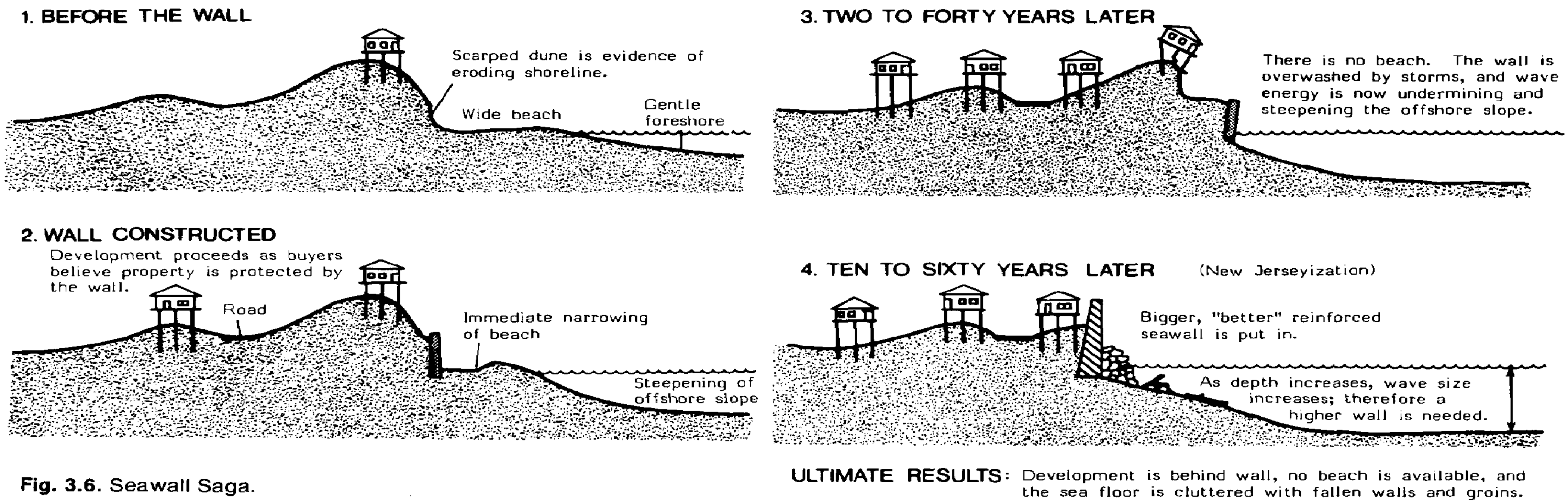


Fig. 3.6. Seawall Saga.

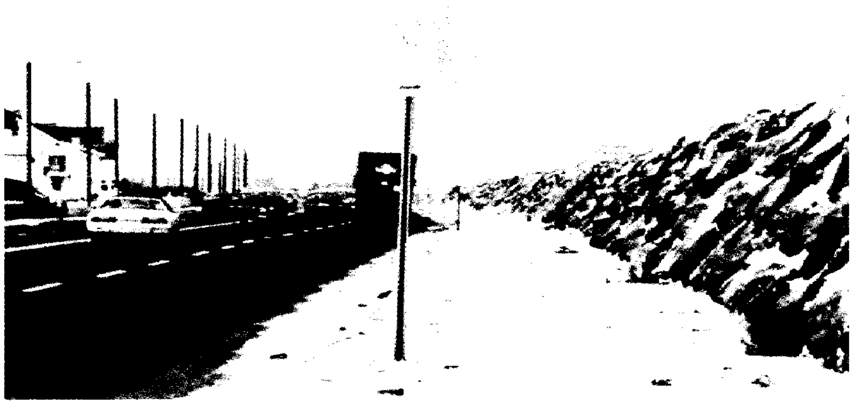


Fig. 3.7. Monmouth Beach, New Jersey, seawall. Photo by Orrin Pilkey, Jr.

Sea-level rise: built-in obsolescence

If the techniques of shoreline stabilization have such a poor record, why are they built? Rest assured, such structures were neither designed to fail nor to enhance erosion problems. When the earliest of these structures was built, the understanding of shoreline processes was not what it is today. Furthermore, most engineering projects have a design life of less than 50 years. In other words, long-term geologic effects beyond 50 years are not considered. In fact, 10 to 20 years is a more common design life of shoreline engineering projects. The experiences of the Cape May, New Jersey, jetties and seawall, Miami Beach, and numerous other projects that represent long-term future commitments should tell the engineers that for all new projects the long-term consequences must be considered, figured into benefit/cost ratios, and entered into the final decision of whether or not to pursue the stabilization project. We suggest that their conclusions will be against future projects except in a few highly urbanized areas where there is no alternative.

Several reasons account for the long-range failure of shoreline stabilization schemes, but the most important and fundamental of them is that the sea level is rising. Along the Gulf Coast this rise may amount to about 1 foot per century. We do not know precisely why the sea level is rising, but it is probably because the polar ice caps are continuing to melt. In a report released in 1983 the U.S. Environmental Protection Agency reinforced the National Academy of Science warning that even within this century the warming effect of excess carbon dioxide produced by the burning of fossil fuels will cause increased melting of the ice. As more coal and oil are burned, more carbon dioxide is released into the atmosphere, causing it to act as a giant greenhouse. The atmosphere lets light energy in, but tends not to let heat energy out, so a gradual warming occurs and more glacial ice melts in summer than freezes in winter. This so-called "greenhouse effect" is probably the cause of today's sea-level rise. All indications are that the rise in sea level will be with us for a long time, and it may well accelerate.

All along the American shore, what we now call beach erosion is largely a response to the sea-level rise. Barrier islands are beginning a long process (a very rapid process in terms of geologic time) of slimming down prior to landward migration. At the same time, of course, mainland shores must also erode, otherwise the islands will soon "bump into" the mainland and no longer will they be islands. Part of the Fort Morgan Peninsula may be an example of such welding onto the mainland shore by an earlier barrier island. This attachment occurred thousands of years ago during an earlier high stand of sea level. Island formation and beach migration are dependent on sea-level rise, and under normal circumstances the sea-level rise does not threaten or endanger islands or beaches in any way.

What happens when we stabilize a barrier island or beach, that is, what happens when we try to stop islands or beaches from migrating? Basically shoreline engineering holds the beach, or the island, where it does not want to be held. The beach or island is said to be out of equilibrium. It also can be said to be in trouble!

If the shoreline is prevented from migrating as the sea level rises and is held in its original position, it will be placed in increasing jeopardy as the years roll by. As an extreme example, imagine what would have happened if engineers had tried to hold the shoreline in place when it first formed at the edge of the continental shelf 18,000 years ago. Now it would be 300 feet under water, and the seawalls between land and sea indeed would have to be spectacular in size! That is basically what engineers are trying to do today. On a smaller scale they are attempting to hold back a sea that is rising, but the designs have not taken this phenomenon into account. Thus, obsolescence is built into the structures.

What specifically happens in the long run as the beach becomes increasingly out of equilibrium is shoreface steepening. It appears from the New Jersey experience that the offshore beach profile down to a depth of perhaps 30 feet gets steeper and steeper. As a consequence, waves striking the shoreline get larger and larger. Shoreline stabilization schemes evolve from replenishment to replenishment and groins, to small seawalls, to bigger and better seawalls, to even bigger and better seawalls (fig. 3.6). As the sea outflanks a structure, it must be extended, and more and more shoreline becomes armored. Thus, the eventual effect of ignoring the sea-level rise is New Jerseyization! The message for the Gulf Coast and all coastal states is clear: to choose shoreline stabilization as the solution to coastal hazard mitigation will be an expensive road to follow, and one that will lead ultimately to failure.

The future of beach "protection": increasing natural and social resistance

Much of the Mississippi coast is already wed to shoreline stabilization schemes such as seawalls, groins, and artificial beaches (Pascagoula, all of Harrison County from Biloxi to Pass Christian, and Bay St. Louis–Waveland). Other Gulf-front and bay shores are headed in this direction. Coastal residents in these areas should consider the future of such engineered shorelines, a future that hinges on natural events and the social commitment in dollars and technology to maintain these engineering programs.

Shoreline stabilization and beach protection that rely on engineering structures or nourishment schemes face an uncertain future. Some of the possible events and responses are these:

1. Closely spaced "big" hurricanes continue to occur: natural and artificial beaches disappear or structures are damaged and destroyed.
2. Sea level continues to rise, possibly at an accelerating rate: beaches erode faster and structures are flooded.
3. Adjacent coastal areas, passes, or harbor mouths are stabilized, cutting off natural sand supplies: natural and artificial beaches erode faster.
4. Suitable sand for renourishment projects becomes increasingly scarce: the cost to nourish beaches increases or unsuitable sand is used causing longer intervals between nourishment or increased erosion rates.
5. Changes in the economic climate increase costs of structure maintenance or beach nourishment: taxpayer resistance increases to paying for such projects, causing postponement or a reduction in scale of the project.
6. Increases in the number of "endangered" beach developments within the state and nation increase the demand for similar projects: less federal and state money is available for the older projects, and taxpayer resistance increases when the local community is asked to bear a larger share of the cost.
7. Some combination of the above: the beach either disappearing or becoming New Jerseyized with the rubble of failed structures.

A philosophy of shoreline conservation: "We have met the enemy and he is us"

In 1801 Postmaster Ellis Hughes of Cape May, New Jersey, placed the following advertisement in the Philadelphia *Aurora*:

> The subscriber has prepared himself for entertaining company who uses sea bathing and he is accommodated with extensive house room with fish, oysters, crabs, and good liquors. Care will be taken of gentlemen's horses. Carriages may be driven along the margin of the ocean for miles and the wheels will scarcely make an impression upon the sand. The slope of the shore is so regular that persons may wade a great distance. It is the most delightful spot that citizens can go in the hot season.

This was the first beach advertisement in America and sparked the beginning of the American rush to the shore.

In the next 75 years 6 presidents of the United States vacationed at Cape May. At the time of the Civil War it was certainly the country's most prestigious beach resort. The resort's prestige continued into the twentieth century. In 1908 Henry Ford raced his newest model cars on Cape May beaches.

Today Cape May is no longer found on anyone's list of great beach resorts. The problem is not that the resort is too old-fashioned, but that no beach remains on the cape (fig. 3.8).

The following excerpts are quoted from a grant application to the federal government from Cape May City. It was written by city officials in an attempt to get funds to build groins to "save the beaches." Though it is possible that its pessimistic tone was exaggerated to enhance the chances of receiving funds, its point was clear:

> Our community is nearly financially insolvent. The economic consequences for beach erosion are depriving all our people of much needed municipal services. . . . The residents of one area of town, Frog Hollow, live in constant fear. The Frog Hollow area is a 12 block segment of the town which becomes submerged when the tide is merely 1 to 2 feet above normal. The principal reason is that there is no beach fronting on this area. . . . Maps show that blocks have been lost, a boardwalk that has been lost. . . . The stone wall, one mile long, which we erected along the ocean front only five years ago has already begun to crumble from the pounding of the waves since there is little or no beach. . . . We have finally reached a point where we no longer have beaches to erode.

Fig. 3.8. Cape May, New Jersey, seawall (1976). Note the absence of a beach. Photo by Orrin Pilkey, Jr.

Alabama and Mississippi will not have to wait a century and a half for this crisis to reach their shores. The pressure to develop is here and increasing. Like the original Cape May resort, our structures are not placed far back from the shore; nor have we been so prudent as to always place structures behind dunes or on high ground. Consequently, our coastal development is no less vulnerable to the rising sea than was Cape May's, and no shoreline engineering device will prevent its ultimate destruction. The solution lies in recognizing certain "truths" about the shoreline.

Truths of the shoreline

Cape May is the country's oldest shoreline resort. Built on a shoreline that migrates, it is a classic example of a poorly developed shoreline where communities chose to confront nature rather than work with it. Alabama and Mississippi can learn from New Jersey's mistakes.

From examples of Cape May and other shoreline areas, certain generalizations or "universal truths" about the shoreline emerge quite clearly. These truths are equally evident to scientists who have studied the shoreline and old-timers who have lived there all their lives. As aids to safe and aesthetically pleasing shoreline development, they should be the fundamental basis of planning in any coastal zone.

There is no erosion problem until a structure is built on a shoreline. Beach erosion is a common, expected event, not a natural disaster. Shoreline erosion in its natural state is not a threat to the coast. It is, in fact, an integral part of coastal evolution (see chapter 2) and the entire dynamic system. When a beach retreats, it does not mean that it is disappearing; it is migrating. Many developed shorelines, especially on barrier islands, are migrating at surprisingly rapid rates, though only the few investigators who pore over aerial photographs are aware of it. Whether the beach is growing or shrinking does not concern the visiting swimmer, surfer, hiker, or fisherman. It is when man builds a "permanent" structure in this zone of change that a problem develops.

Construction by man on the shoreline causes shoreline changes. The sandy beach exists in a delicate balance with sand supply, beach shape, wave energy, and sea-level rise. This is the dynamic equilibrium discussed in chapter 2. Most construction on or near the shoreline changes this balance and reduces the natural flexibility of the beach. The result is change that often threatens man-made structures. Dune removal, which often precedes construction, reduces the sand supply used by the beach to adjust its profile during storms. Beach cottages—even those on stilts—may obstruct the normal sand exchange between the dunes, beach, and the shelf during storms. Similarly, engineering devices interrupt or modify the natural cycle (see chapter 2 and figs. 2.7, 3.5, and 3.6).

Shoreline engineering protects the interests of a very few, often at a very high cost in federal and state dollars. Shoreline engineering is carried out to save beach property, not the beach itself. Shore stabilization projects are in the interest of the minority of beach property owners rather than the public. If the shoreline were allowed to migrate naturally over and past the cottages and hot dog stands, the fisherman and swimmer would not suffer. Yet beach property owners apply pressure for the spending of tax money—public funds—to protect the beach. Since these property owners do not constitute the general public, their personal interests do not warrant the large expenditures of public money required for shoreline stabilization.

Exceptions to this rule are the beaches near large metropolitan areas. The combination of extensive high-rise development and heavy beach use (100,000 or more people per day) affords ample economic justification for extensive and continuous shoreline stabilization projects. For example, to spend tax money for replenishing Coney Island, which accommodates tens of thousands of people daily during the summer months, is more justifiable than to spend tax dollars to replenish a beach that serves only a small number of private cottages. In the case of the former, beach maintenance is in the interest of the public that pays for it. Whereas in the latter case, the expenditure amounts to middle-class welfare.

Shoreline engineering destroys the beach it was intended to save. If this sounds incredible to you, drive to New Jersey and examine their shores. See the miles of "well-protected" shoreline—without beaches (fig. 3.9)! This truth applies equally to the Gulf Coast. The 27 miles of Harrison County, Mississippi, seawall contributed to the loss of the beach. The beach today in front of the seawall was built by man and must be maintained in order to exist.

The cost of saving beach property through shoreline engineering is usually greater than the value of the property to be saved. Price estimates for shoreline engineering projects are often unrealistically low in the long run for a variety of reasons. Maintenance, repairs, and replacement costs are typically underestimated because it is erroneously assumed that the big storm, capable of removing an entire beach replenishment project overnight, will somehow bypass the area. The inevitable hurricane or storm, moreover, is viewed as a catastrophic act of God or a sudden stroke of bad luck for which one cannot plan. The increased potential for damage resulting from shoreline engineering is also ignored in most cost evaluations. In fact, very few shoreline engineering projects would be funded at all if those controlling the purse strings realized that such "lines of defense" must be perpetual.

Once you begin shoreline engineering, you can't stop it! This statement, made by a city manager of a Long Island Sound community, is confirmed by shoreline history throughout the world. Because of the long-range damage caused to the beach it "protects," this engineering must be maintained indefinitely. Its failure to allow the sandy shoreline to migrate naturally results in a steepening of the beach profile, reduced sand supply, and therefore accelerated erosion (see chapter 2). Thus, once man has installed a shoreline structure, "better"—larger and more expensive—structures must subsequently be installed, only to suffer the same fate as their predecessors (fig. 3.9).

History shows us that there are 2 situations that may terminate shoreline engineering. First, a civilization may fail and no longer build and repair its structures. This was the case with the Romans, who built mighty seawalls that are now ruins or forever lost. Second, a large storm may destroy a shoreline stabilization system so thoroughly that people decide to throw in the towel. In America,

Fig. 3.9. Beach loss and New Jerseyization of shore resulting from shoreline engineering. Photo by Bill Neal.

however, such a storm is usually regarded as an engineering challenge and thus results in continued shoreline stabilization projects. As noted in chapter 2, rubble from 2 or more generations of seawalls remains off some New Jersey beaches! A smaller scale example occurs at Waveland, Mississippi.

The solutions

1. Design to live with the flexible coastal environment. Do not fight nature with a "line of defense."
2. Consider all man-made structures near the shoreline temporary.
3. Accept as a last resort any engineering scheme for beach restoration or preservation, and then, only for metropolitan areas.
4. Base decisions affecting coastal development on the welfare of the public rather than the minority of shorefront property owners.
5. Let the lighthouse, beach cottage, motel, or hot dog stand fall when its time comes.

Questions to ask if shoreline engineering is proposed

When a community is considering some form of shoreline engineering, it is almost invariably done in an atmosphere of crisis. Buildings and commercial interests are threatened, time is short, an expert is brought in, and a solution is proposed. Under such circumstances the right questions are sometimes not asked. The following is a list of questions you might ask if you find yourself a member of such a community.

1. Will the proposed solution to shoreline erosion damage the recreational beach? in 10 years? in 20 years? in 30 years? in 50 years?
2. How much will maintenance of the solution cost in 10 years?

in 20 years? in 30 years? in 50 years? Where will the funds come from?
3. If the proposed solution is carried out, what is likely to happen in the next big storm? mild hurricane? severe hurricane?
4. What has been the erosion rate of the shoreline here during the last 10 years? 20 years? since the late 1930s (the time of the first coastal aerial photography)? since the mid-1800s (the time when the first accurately surveyed shoreline maps were produced by the old U.S. Geodetic Survey)?
5. What will the proposed solution do to the beach front? Will the solution for one portion of a shoreline create problems for another portion?
6. What will happen if an adjacent inlet migrates? closes up? What will happen if the tidal delta offshore from the adjacent inlet changes its size and shape or if the channel moves?
7. If the proposed erosion solution is carried out, how will it affect type and density of future beach-front development? Will additional controls on beach-front development be needed at the same time as the solution?
8. What will happen 20 years from now if the inlet nearby is dredged for navigation? if jetties are constructed? if seawalls and groins are built nearby?
9. What is the 50- to 100-year environmental and economic prognosis for the proposed erosion solution if predictions of an accelerating sea-level rise are accurate?
10. If stabilization—for instance, a seawall—is permitted here, will this open the door to seawalls elsewhere? (The answer to this one has always been "yes" in most other coastal states.)
11. What are the alternatives to the proposed solution to shoreline erosion? Should the threatened buildings be allowed to fall in? Should they be moved? Should tax money be used to move them?
12. What are the long-range environmental and economic costs of the various alternatives from the standpoint of the local property owners? the beach community? the entire shoreline? the citizens of the state and the rest of the country?

4. Selecting a site along the Alabama-Mississippi coast

No coastal locality is absolutely safe. Given the right conditions, hurricane, flood, wind and wave erosion, overwash, and inlet formation can attack any area in the coastal zone. Furthermore, human activity, particularly construction, almost always reduces the stability of the natural environment. Man-made structures are static (immobile); when placed in a dynamic (mobile) system, they tend to disrupt the balance of that system. Interference with sand supply, disruption of plant cover, topographic alteration, and similar effects associated with man-made structures actually create conditions favorable to the damage or loss of those structures. When building a new structure or buying an existing one, you should first evaluate the safety of the general area in which you are locating, and then similarly evaluate the specific site.

Choosing your area: the first step to safety

Though some areas are considerably safer for development than others, all are vulnerable to the natural processes at work in the coastal zone. Structures placed in the *most* stable areas (subject to less movement or change) are least likely to be damaged or destroyed. If we can identify such areas as well as rates and intensities of natural physical activity, we will have a basis for choosing a specific homesite or business site. Consider, for example, a river and the floodplain (flat area) next to it. Even casual observation reveals that the river floods. If this system is observed for a long period of time, it may be noted that the time and size of the floods follow a pattern. The area next to the river is flooded every spring, while the middle floodplain of the river is covered only every 5 to 10 years. Once or twice in a lifetime, a devastating flood will cover the entire floodplain. These observations have been confirmed by detailed stream studies. Thus, we can determine and predict the frequency and size of floods in a given area, though we cannot predict exactly when a flood of a given size will actually occur. We can then describe an individual flood as a 1-in-10-year flood, or a 1-in-50-year flood, based on the frequency of a given flood level.

Obviously we would not want to build a house or business in an area that is flooded once (or more) every year, or even every 10 years; given the choice we would rather locate where the likelihood of flooding is once in 50 to 100 years. The decision to locate in a flood-prone area would be determined by how essential it is to be there and the level of economic loss we are willing to sustain.

In a like manner we also can predict the frequency and level of storm flooding in coastal areas (table 4.1, see also reference 69, appendix C). Although the frequency and levels can be predicted, the time of a given storm is not yet predictable. Thus, if a 1-in-25-year storm-flood level of 8 to 9 feet is expected for a certain stretch of coast, it would be sensible to build at an elevation greater than 9 feet above mean sea level. This concept has been incorporated in many coastal zone building codes, and it is why new construction

Table 4.1 Storm stillwater surge levels for 1-in-25-, 50-, and 100-year storms (in feet above mean sea level)

	1-in-25	1-in-50	1-in-100
Destin beaches, Florida	—	—	10.5
Fort Walton beaches, Florida	—	—	9.2
Santa Rosa Island, Florida	—	—	10.5
Perdido-Wolf Bay area, Alabama	4.9	5.7	6.5
Bayou St. John Area, Alabama	6.5	7.5	8.5
Fort Morgan-Gulf Shores, Alabama	8.7	10.1	11.4
Mobile Bay, Alabama	7.9	9.3	10.6
Dauphin Island	8.1	9.8	11.5
Grand Bay-Bayou La Batre, Alabama	9.4	11.4	13.3
Pascagoula, Mississippi	10.0	12.2	14.2
Biloxi, Mississippi	10.4	12.9	15.4
Bay St. Louis, Mississippi	12.0	14.8	17.4

Source: Adapted from U.S. Army Corps of Engineers' publications (references 7 and 16, appendix C).

is required to be a certain elevation above ground level (usually on "stilts"; see chapter 6 on construction).

The 100-year flood level is a standard used for both inland and coastal areas in determining areas eligible for the National Flood Insurance Program. Persons unfamiliar with this concept sometimes mistakenly believe that after such a flood level occurs, it will not happen again for 100 years. The fact is that a flood of such magnitude can occur in successive years, or twice in one year, and so on. The flooding along the Pearl River over the last several years has taught floodplain residents a hard lesson about flood recurrence. And those Gulf residents whose property was twice damaged or destroyed by hurricanes over an 11-year interval (Camille in 1969 and Frederic in 1979) know that the 100-year storm-surge level is just an average.

Perhaps it is better to think of a 100-year flood as a level of flooding having a 1 percent statistical probability of occurring in any given year (but each and every year). During the life of a house within the flood zone, a house with a 30-year mortgage, there is a 26 percent probability that the property will be flooded. The chance of losing your property becomes roughly 1 in 4, rather than 1 in 100. Because of such risk the federal government has tightened requirements and raised the price of flood insurance in the coastal zone (see chapter 5).

In evaluating an area, then, 2 important questions need to be asked: Is the area (community) within the flood zone? And is flood insurance available?

Another important question is: How has the shoreline responded to past human activity, particularly construction? The shoreline is not necessarily safe merely because it has been developed. The new and modern development of Gulf Shores, West Beach, or on the Fort Morgan Peninsula gives no indication of the near total destruction of Hurricane Frederic. Other than steps leading up to a few vacant lots, there is no indication of what Hurricane Camille did to the urbanized Mississippi coast.

What are some of the clues of a troubled shoreline? The presence of groins, seawalls, or revetments on the beach tells you the shoreline is subject to erosion, now compounded by the stabilization structures. Such a shoreline certainly is to be avoided. Removal of vegetation, for purposes of construction or to get a better view of the sea, may increase the potential for storm damage or create a blowing sand nuisance. Roads to the beach built through the dune line may act as overwash passes. Removal of dunes or construction in front of them is an invitation to storm disaster. Areas of extensive, artificially filled marshes are likely to be flooded and commonly experience groundwater problems. Instability of bluff shorelines, such as adjoining Mobile Bay and Biloxi Bay, also is increased by adjacent construction.

The political infrastructure of your prospective coastal area may have as strong a bearing on its overall safety as the natural system. Unchecked growth or unenforced building and sand dune codes are examples of social conditions that may create threats to health or safety. Overloaded sewage treatment systems, inadequate or unsafe escape routes, loss of natural storm protection, structures lacking storm worthiness, and vulnerable utilities are but a few examples of man-made problems.

Regardless of the coastal area you choose, site selection is the next important step.

Selecting your site: playing the odds

Human nature is such that we are willing to gamble if the potential reward is worth the risk. In the case of the coast the rewards are the amenities of the seashore and other coastal environments. The risk is losing your property. Like smart gamblers who know the odds and try to reduce the house advantage, property buyers and owners can and should identify the natural odds of coastal hazards and act accordingly.

Structures placed in the least dynamic zones (stable areas subject to less movement or change) are less likely to be damaged. If we can identify such areas, as well as the rates and intensities of natural physical activity, we have a basis for evaluating site safety, selecting the site that provides the greatest protection against natural hazards, and taking appropriate precautions. The previous example of identifying the flood zone illustrates the point. If you expect a 1-in-25-year storm-surge flood level of 8 feet for a particular site, it would be sensible either to avoid the site or to build at an elevation of greater than 8 feet. Because storm waves will further increase that flood height, you should seek even higher elevations in addition to using a construction technique that raises the house several feet off the ground (see chapter 6).

What other clues can we look for in evaluating site safety and stability?

Stability indicators: what to look for at your site

Along the Alabama-Mississippi coasts a number of environmental characteristics indicate the natural history of a given area. In revealing how dynamic an area has been through time, these characteristics aid prospective builders and buyers in deciding whether a site offers protection against natural hazards or not. Natural indicators include terrain and land elevation, vegetation, soil profile, and even seashells.

Terrain and elevation

Terrain and elevation are good measures of an area's safety from various adverse natural processes. Low, flat areas are subject to destructive wave attack, overwash, storm-surge flooding, and blowing sand. Table 4.1 shows the expected storm-surge levels for different parts of the Florida-Alabama-Mississippi coasts. On islands, peninsulas, and areas backed by lagoons, embayments, or coastal lakes and ponds, the flooding may come from the direction of those bodies of water rather than from the direction of the Gulf. Hurricane Camille generated flood levels on the order of 25 feet. References 61 and 62 (appendix C) show the areas flooded by Camille and Frederic.

High elevations are always preferable to lower elevations. However, stay away from the retreating edges of eroding bluffs such as those that occur along parts of Mobile Bay and Mississippi Sound. The higher elevations of sand dunes also afford protection, but keep in mind that sand dunes are unstable.

Vegetation

Vegetation may indicate environmental stability, age, and elevation. In general, the taller and thicker the vegetative growth, the more stable the site and the safer the area for development. Maritime forests grow only at elevations high enough to preclude frequent flooding. In addition, since a mature live oak or pine forest takes many years to develop, the homeowner or prospective buyer can be assured further that the forest areas generally provide the safest homesites in the coastal zone. Of course, safe is a relative term. Hurricanes do knock down trees and inflict wind damage in forested areas. One should evacuate from even the "safest" coastal site in the event of an impending hurricane.

The exception to using forest as an indicator of stability is where rapidly eroding shorelines have advanced into the forest. This is occurring along parts of the Mobile Bay shore, along the mainland shore of Mississippi Sound in Mobile County and Jackson County, and on Dauphin Island east of Bienville Beach. Fallen trees and stumps on the beach and in the surf zone identify localities to be avoided.

Bare, unvegetated areas usually indicate erosion or moving sand and are unsafe for development.

Soil profiles

Soil profiles may give a clue to building site stability. White-bleached sand overlying yellow sand to a depth of several feet suggests stability, because such a soil profile requires a long period of time to develop. Note the soil profile by looking in road cuts, along canals, or in a pit you have dug. Red sands do not occur naturally in most coastal areas, so beware where your soil profile includes this red material; it probably means that a low area has been filled, and may, or may not, be suitable for development. Keep in mind that even formerly stable, forested areas can be eroded by a migrating shoreline, so you may find a "stable" soil profile in an unstable position. Avoid areas where profiles show layers of peat or other organic materials. Such layers have a high water content and lack the strength to support an overlying structure. The weight of a house can compress the layers, causing the house to sink. Furthermore, such soil conditions cause septic tank problems.

Seashells

Seashells also provide clues to the natural or man-made processes that have occurred in an area. A mixture of brown-stained and natural-colored shells is often washed onshore from the Gulf during storms. Shells with these mixed colors, then, indicate overwash zones. Do not build where overwash has occurred; it is likely to occur again in that area. If you must build, do so on stilts so that the building allows overwash to pass beneath the structure.

Mixed black and white shells without brown or natural-colored shells are almost a certain sign that material has been pumped or dredged from the sound or bay. Such material is used to artificially fill low areas or passes, or to nourish an eroding beach. Thus, such a shell mixture may indicate an unstable area where development should be avoided.

Coastal environments: what natural processes are operating at the site

Inland developments typically occupy a single environment, such as a pine forest or former pastureland. In contrast, the coastal zone consists of small areas of very different environments, and typical developments overlap environmental boundaries without regard to the consequences. By knowing what environment(s) a lot occupies, you can identify prevailing conditions that may or may not be conducive to development. In addition to the beach, environmental features include primary dunes, overwash fans, grasslands, passes, maritime forests and thickets, marshes, and bluffs (fig. 2.9).

Primary dunes

Primary dunes usually are defined as the row of dunes closest to the Gulf, although a distinct line or row may not be obvious. In some places these dunes may be totally absent. Where present, such dunes serve as a sand reservoir that feeds the beach during storms and provide elevation as a temporary line of defense against wind and waves. The temporary nature of dunes was demonstrated in the area east of Gulf Shores, Alabama, and just west of the public fishing pier. Before Hurricane Frederic (September 12–13, 1979) that area had some of the finest and best developed primary dunes on the Gulf Coast. The hurricane waves and storm surge completely removed the dunes, however; damage inland was lessened because the storm's fury was spent on eroding the dunes.

Primary dunes are the natural main line of defense against erosion and storm damage to man-made structures. This line of defense is "leaky" because of the discontinuous nature of the dune line and overwash passes between the dunes. When man interferes with the dune system, both the natural and man-made systems suffer. We must recognize the mobility of dune systems, even those stabilized by vegetation. By prohibiting vehicles on the dunes, and by building boardwalks and footbridges *over* the dunes rather than building footpaths *through* them, we may preserve the dunes. Avoiding the construction of seawalls, groins, and bulkheads also preserves dunes by assuring that the sand flow that feeds them is not interrupted.

If dunes are destroyed or threatened, there are some remedial steps that can be taken to stabilize them artificially. Planting vegetation types that can live in the dune environment serves to stabilize existing dunes and encourages additional dune growth (see references 71 through 80, appendix C). Snow fencing is commonly used to trap sand and to initiate or increase dune growth.

The high elevation of a dune does not in itself make a site safe. An area with a high *erosion* rate is quite likely to lose its dune protection during the average lifetime of a cottage. Even setback ordinances, laws which require that buildings be placed a minimum distance behind the dune, *do not* guarantee long-term protection. Hurricane Frederic removed much of the protective dune line on which such an Alabama law was based. Post-Frederic construction was still placed as if the dune line remained. These beach-front cottages and condominiums will not fare well in the next hurricane because they are without any natural protection! Locating *on* a primary dune is nearly as dangerous. In such a location you should expect to lose your cottage or condo during the next major storm.

Dune fields

Dune fields are open, bare to grassy sand dune areas found between the primary dunes and the forest (if present), or between the primary dunes and the sound or bay if such a body of water exists. Some of these dunes are active, with the sand and dune positions continually shifting; other dune fields are temporarily stable and do not move much at all.

Stable dune fields may offer sites that are relatively safe from the hazards of wave erosion, overwash, and storm-surge flooding provided that the elevation is sufficiently high. However, digging up or disturbing the dunes for construction may cause blowing sand, the destabilization of dune vegetation, and increasing sand movement. Do not build where dunes show bare, unvegetated surfaces; such dunes are active.

Overwash fans

Overwash fans develop when water, thrown up by waves and storm surge, flows between and around dunes or across flat stretches of coastal property into bodies of water landward from the beach. Such overwash waters carry sand and deposit it in flat, fan-shaped masses (fig. 4.1). They also transport brown, white, and natural-colored shells inward from the beach. These fans provide sand to form and maintain dunes and build up the elevation.

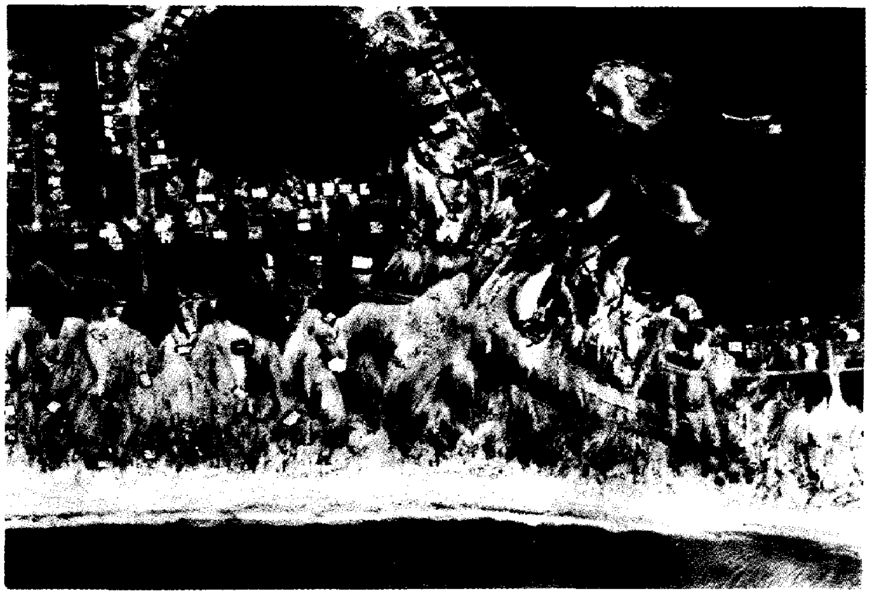


Fig. 4.1. Overwash fans produced by Hurricane Frederic on Dauphin Island, 1979. Note that the lobe-shaped masses of sand bury and block the only escape route from the island. Photograph provided by the Topographic Bureau of the Florida Department of Transportation.

Although the overwash process is constructive in the long term, during actual fan formation erosion and destruction of structures are likely to occur. When primary dunes are high and continuous, overwash is relatively unimportant and restricted to the beach and near-shore area. This case is illustrated on the extreme western end of the Fort Morgan Peninsula. Where dunes are absent, low, or discontinuous, overwash fans may extend across narrow necks of land between bodies of water as they do on the western end of Dauphin Island, Petit Bois Island, Ship Island, Horn Island, and Cat Island, and near Gulf Shores where overwash into Little Lagoon and Shelby Lakes occurred during Hurricane Frederic. During severe hurricanes, only the highest elevations (generally above 15 to 20 feet) are safe from overwash.

Overwash may damage or bury man-made structures. Roads may be buried (fig. 4.1) and escape routes blocked. Level roads cut straight to the beach often become overwash passes during storms, especially where roads cut *through* dunes rather than *over* them. Thus, the roads built to increase development may contribute to its destruction.

Try to avoid building on overwash fans, especially if fresh or unvegetated. Such areas may be difficult to recognize if fans have been destroyed or modified by bulldozing or sand removal. If no alternative site is available, you must build on stilts and allow overwash to continue and to build up sand. Use overwash deposits removed from roads and driveways to rebuild damaged dunes; do not remove the sand from the area.

Grasslands

Grasslands are located either behind dune fields or adjacent to salt marshes. Such areas may be relatively flat, built up as a terrace of coalescent overwash fans, and generally are subject to future flooding and overwash. Natural grasslands may be difficult to distinguish from artificial bulldozer-flattened developments, but the former is characterized by a diversity of plants (for example, saltmeadow cordgrass, yucca, cactus, and thistle).

Passes (inlets)

Passes, or inlets, are the channels that separate islands and/or lead into bodies of water inland from the beach (for example, Little Lagoon). Some passes are permanent, while others usually form, or reopen, during hurricanes or severe storms (fig. 4.2). As a hurricane approaches a coastal area, strong offshore winds drive storm-surge waters and waves against the shore, into adjacent bodies of water, and up embayments. As the storm passes, the wind either stops blowing or shifts to blow seaward, causing water to return seaward. If existing passes do not allow the water to escape fast enough, a new pass may be cut from the "land" side.

Low, narrow areas lacking extensive salt marsh and/or opposite river or estuary mouths are likely spots for pass development. They should therefore be avoided as building sites. Parts of Perdido Key, West Beach, and Dauphin Island in Alabama, Deer Island, and the barrier islands of Mississippi are particularly susceptible to pass formation.

Once formed, a pass may migrate laterally, destroying structures and property in its path, or it may close naturally. Along the Alabama-Mississippi coast, passes formed in the offshore barrier islands tend to close rapidly but reopen in subsequent storms, although the pass between the two parts of Ship Island has remained open since it was cut by Hurricane Camille in 1969. Because passes (inlets) tend to reappear in the same places, such sites are not good places to build structures. For example, Dauphin Island has been cut twice in this century in the same area, and that area is now *developed*!

Sediment carried through passes, either into the sound or seaward, builds an underwater shoal referred to as a *tidal delta*. The sediment may accumulate to fill the pass or cause shoaling so that the pass is unnavigable. The strong westerly sand transport along the barrier island tends to cause shoaling in the eastern parts of the passes, forcing a westward migration. Today most larger passes are dredged to keep the channels open for navigation, so that the natural healing and migration processes are less common. The associated tidal deltas also are important natural sand reservoirs that contribute to coastal equilibrium. Sand Island off the mouth of Mobile Bay is an emergent portion of such an ebb-tidal delta.

Forest, thicket, and shrub areas

Forest, thicket, and shrub areas are generally the safest places for cottage construction. Under normal conditions, overwash, flooding, and blowing sand are not problems in these vegetated environments. The plants stabilize the underlying sediment and offer a protective screen.

If you are building in a vegetated area, preserve as much vegetation as possible, including undergrowth. Trees are excellent pro-

Fig. 4.2. Storm pass produced by Hurricane Frederic, 1979, in the Shelby Lakes area east of Gulf Shores, Alabama. Note that the pass cuts the only road through the area (left to right), and that the road is burried by overwash and is washed out in several places. Photograph provided by the Topographic Bureau of the Florida Department of Transportation.

tection from flying debris during hurricanes. Remove large, dead trees and limbs from the construction site, but conserve the surrounding forest to protect your home. Stabilize bare construction areas as soon as possible with new plantings.

The presence of an active dune field on the margin of a forest may threaten the forest. For example, on Dauphin Island where large dunes have migrated landward into a pine forest, the re-exposed trunks of trees buried and killed as the dunes migrated are now seaward of the present dunes. These dunes have been artificially stabilized by sand fencing and planted vegetation.

Marshes

Marshes are prolific breeding areas for many organisms such as fish, birds, crabs, and shrimp. Their extensive shallows provide considerable protection against wave erosion. In the past, however, marshes have been filled to expand land areas on which to build. Many examples can be noted around Mobile, Pascagoula, Biloxi, and on the north side of the Fort Morgan Peninsula. Areas around finger canals (fig. 4.3) often have been built up from dredge and fill of marsh.

Nature usually takes revenge on those who occupy this land. Buried marsh provides poor support for foundations, and the groundwater reservoir usually is destroyed. Thus, such building sites may have an inadequate supply of freshwater unless connected to a municipal system. If septic systems are needed in the absence of a sewer system, they often do not function properly. In addition, effluent waste from such sites has closed adjacent marshes to shellfishing.

Fig. 4.3. Finger canal. Photo by Bill Neal.

Marshes should not be dredged or filled. It is illegal to do so without a permit. New marsh may indicate overwash being carried into the sound to provide shallows for marsh growth, another clue to active overwash areas. Where sound shorelines are eroding, it is possible to create new marshes to stabilize the shoreline. This method is highly preferable to bulkheading; it not only protects the shoreline, but it also allows for the formation of new living areas for marine plants and animals. Bay-front property owners should encourage marsh growth, rather than remove marsh for easier water access.

Bluffs

Bluffs are the product of a retreating shoreline into an upland. Uplands, of course, are safe for development, but buildings should be located well back from the bluff edge. Wave erosion, especially during storms, undercuts and steepens the slope, which causes slumping. The beach at the base of the bluff is often narrow or absent, and there may be a pile of slumped bluff material (talus) that serves to temporarily protect the base of the bluff. Such material should not be removed. Groundwater seeping through the bluff face contributes to the erosion as material is sapped away. Bluff retreat is usually sporadic, taking place during storms. However, loading the bluff with structures, ground vibration, or adding water to the ground may accelerate bluff retreat. Something as simple as watering a lawn at the edge of a bluff may trigger bluff failure. Bluffs can be partially stabilized through vegetation cover and drainage systems to remove water. The bluffs are sand sources for adjacent beaches, so revetments are not recommended.

Most bluff shorelines are found along the bays, such as in the Fairhope area and the spectacular Red Bluff. Lower bluffs occur along the north side of Sunny Cove in southwest Mobile Bay, west of the Pascagoula River in Jackson County, along parts of Biloxi Bay, and in other embayments.

Water problems: an invisible crisis

One of the more significant hazards to living in the coastal zone, especially in areas not served by a municipal water supply, is contaminated water. Although such pollution has not yet caused an epidemic, its potential to do so threatens much of the developing coast, from individual homes, to small villages, to large developments. Basically the problem involves 3 factors: water supply, waste disposal, and any form of alteration that affects either of them. While finger canals are the most obvious illustration of alteration, keep in mind that dredge-and-fill operations (for example, the channeling of islands or the piling of dredge spoil) and other construction activities of man also may alter the groundwater system.

Water supply

Just as the quality and availability of water determine the plant and animal makeup of a coastal ecosystem, they also determine in part the coastal zone's ability to accommodate man. Water quality is measured by potability, freshness, clarity, odor, and the presence or absence of pathogens (disease-carrying bacteria). Availability implies the presence of an adequate supply, both in quality and quantity.

The only freshwater directly available to many coastal areas, especially barrier islands, is from rainfall. This water seeps through the porous and permeable sands and builds up as a lens or wedge of freshwater. This lens overlies saltwater that seeps into the sediments from the adjacent Gulf, sound, or bay. The higher the land's elevation above sea level, and the greater the accumulation of freshwater, the greater the thickness of the freshwater lens. In theory, for islands and peninsulas, if you assume that many feet of clean sand underlie the area, the thickness of the lens should be about 40 feet for every 1 foot of average island elevation. The top of the freshwater lens is known as the groundwater table, and on most islands it is this shallow reservoir that supplies domestic freshwater.

If too many wells are dug into the groundwater table, the table drops. Early occupants of a development should not be surprised if their shallow wells dry up as the development grows. If many wells are overpumped and the groundwater table goes down, saltwater intrusion may occur. Seeking alternative sources of water such as deep aquifers, or building alternative sources such as municipal water systems (deep wells, pipelines, filtration plants), is expensive.

Shallow groundwater wells also are a major source of domestic water for areas on the mainland adjacent to the coast. Because of tidal effects in the estuaries, surface waters are not primary sources of drinking water.

Large developments draw their water supply from rock units beneath the younger surface sands and muds (for example, Dauphin Island). These aquifers are rock formations that are exposed on the coastal plain (their recharge area) and that dip seaward beneath the coast. The freshwater in such aquifers has been accumulating over thousands of years, but large developments withdraw it faster than it can be replaced (recharged). In effect, the water is being mined, and as it is pulled out the space is filled in with salt-water, contaminating existing wells and destroying the adjacent aquifer as a freshwater source.

As condominiums and high-rises replace cottages, the water demand will increase. Alternatives must be sought, and they may be expensive. Coastal property owners will bear the cost.

Consult the proper authorities about water quality and quantity before you buy! (Also see appendix B, Water resources.)

Waste disposal

Waste water disposal goes hand in glove with water supply. Where municipal sewer systems are lacking, the primary means of waste-water disposal is the home septic system. This system consists of a holding tank, in which solids settle and sewage is biologically broken down, and a drain field that allows water to percolate into the soil. The soil then filters and purifies the water. Unfortunately, the same natural system that is used to cleanse the water is often used to supply water to residences.

Many communities are unaware of the potential water problems they face. In the wake of Hurricane Frederic the Mobile County Health Department issued a series of regulations concerning the repair and replacement of damaged septic systems on Dauphin Island. Officials also reiterated the ban on new septic systems initiated in 1976. The developed eastern half of Dauphin Island is now served by a municipal sewage system. Crowded development, improperly maintained systems, and systems installed in soils unsuitable for filtration have resulted in poorly treated or untreated sewage entering the surrounding environment. Polluted water may flood from septic tanks into domestic wells, spreading hepatitis and other diseases. It also may enter sounds and marshes, contaminating shellfish. Many oyster reefs are closed to harvesting because of contamination by sewage and other pollutants. Others have been killed as they were buried under silt.

Municipal waste treatment plants may be one answer for larger communities, although such plants may become overloaded or inefficient. Stricter enforcement of existing codes, policing of existing systems, and proper site evaluation before issuance of permits should be required by civil officials. In addition, homeowners should learn the mechanics of septic systems in order to prevent malfunctioning or to spot problems early (see Sanitation and septic system permits, appendix B).

Finger canals

A common man-made alteration that causes water problems is the finger canal (figs. 4.3 and 4.4). Finger canal is the term applied to the ditches or channels that are dug for the purpose of providing everyone with a waterfront lot. Canals can be made by excavation alone, or by a combination of excavation and infill of adjacent, low-lying areas (usually marshes). Finger canals can be found in Perdido Bay, on Dauphin Island, and in St. Louis Bay.

The major problems associated with finger canals are the (1) lowering of the groundwater table; (2) pollution of groundwater by seepage of saltwater or brackish canal water into the groundwater table, which also can adversely affect vegetation; (3) pollution of canal water by septic seepage; (4) pollution of canal water by stagnation resulting from lack of tidal flushing or poor circulation of waters; (5) fish kills caused by higher canal water temperatures; and (6) fish kills caused by nutrient overloading and deoxygenation of water.

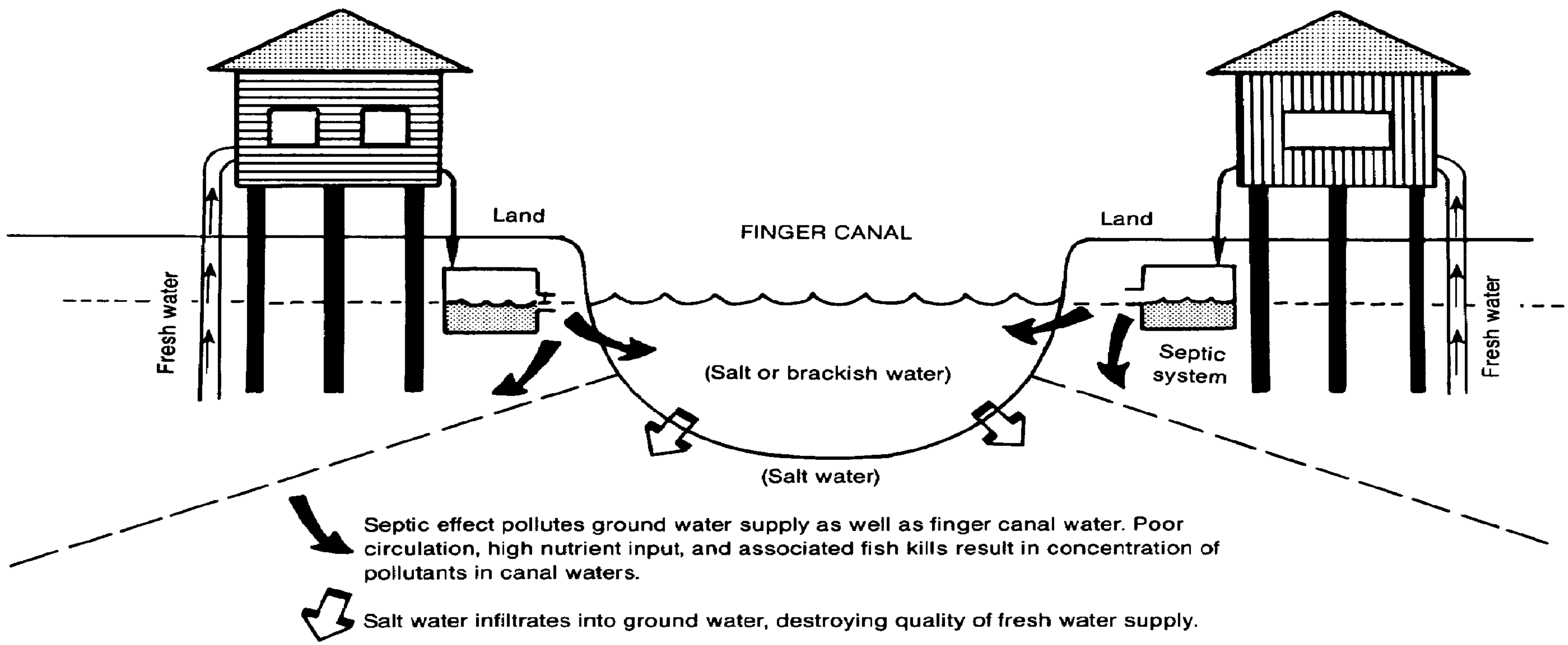


Fig. 4.4. Finger canal model illustrating associated water quality problems.

Bad odors, flotsam of dead fish and algal scum, and contamination of adjacent shellfish grounds are symptomatic of polluted canal water. Thus, finger canals often become health hazards or simply places it is unpleasant to live near. Residents along some older Florida finger canals have built walls to *separate* their cottages from the canal!

Should you consider buying a lot on a canal, remember that canals are generally not harmful until houses are built along them. Short canals, a few tens of yards long, are generally much safer than long ones. Also, while most canals are initially deep enough for small-craft traffic, sand movement can result in the filling of the canals and subsequent navigation problems. Finally, on narrow stretches of land, finger canals dug almost to the Gulf offer a path of least resistance to storm waters and are therefore potential locations for new inlets. Property owners along finger canals on Dauphin Island found themselves owning tiny islands or open water after Hurricane Frederic in 1979 (fig. 4.5), or their canal was choked with sand. The costly redredging and reconstruction of the canals was not a cost these owners anticipated when they purchased their property.

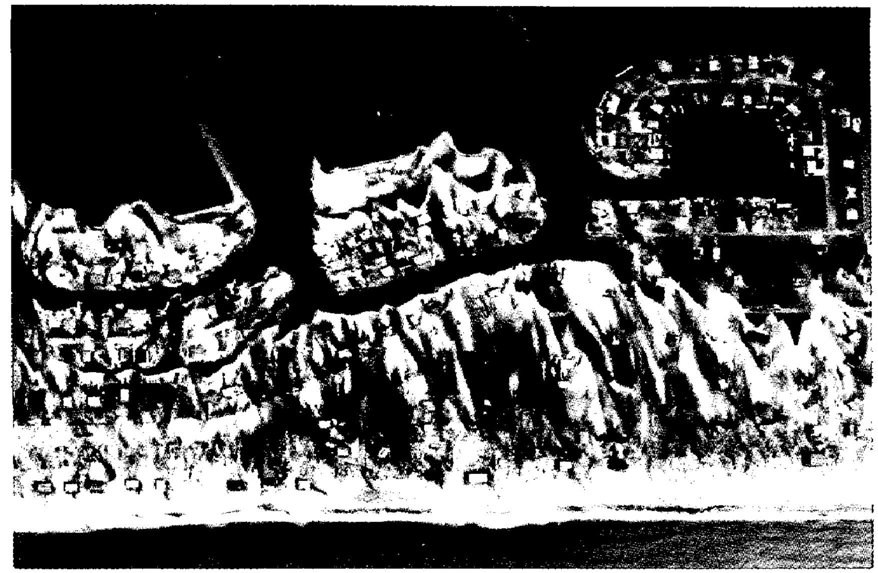


Fig. 4.5. Post-Frederic view of finger canals on Dauphin Island. As the sea washed over the island, the canals became channels that focused erosion, leading to their breaching and the isolation of intercanal property (islands). In other cases, overwash sand filled in canals. Photograph provided by the Topographic Bureau of the Florida Department of Transportation.

Site safety: rules of survival

In order to determine site safety along a hurricane-prone coast it is necessary to evaluate all prevalent dynamic processes that operate. Information on storm surge, overwash, erosion rates, inlet formation and migration, longshore drift, and other processes may be obtained from maps, aerial photographs, scientific literature, or personal observations. Appendix C provides an annotated list of scientific sources; you are encouraged to obtain those of interest to you. Although developers and planners usually have the resources and expertise to use such information in making decisions, they sometimes ignore it. In the past the individual buyer was not likely to seek such information in deciding on the suitability of a given site. Today's buyer should be better informed.

To help the dweller along the Mississippi-Alabama coast, we have drawn a series of diagramatic maps (figs. 4.6, 4.10, 4.14, 4.19, 4.21–4.22, 4.24–4.26, 4.28, 4.30–4.31, 4.33–4.35, 4.37) that summarize information currently available from a cross section of scientific literature. Our conclusions, as represented on the maps, are based on published data, aerial photographs, charts and maps, as well as our personal communications and observations. These maps present zones classified as high, moderate, or low risk on the basis of the summarized information. The risk terms are somewhat arbitrary, but high risk implies at least 3 real dangers from among flood potential, wave impact, erosion, overwash, pass migration or formation, poor escape routes, or the lack of natural protection (for example, dunes, elevation, and vegetation). A low risk zone is an area where only 1 of these hazards is likely.

Buyers, builders, or planners can assess the level of risk they are willing to take with respect to coastal hazards. The listing of specific dangers and cautions provides a basis for taking appropriate precautions in site selection, construction, and evacuation plans. Our recommendation is to avoid high-risk zones. Keep in mind, however, that small maps of large areas must be generalized and that every site must still be evaluated individually. Safe sites may exist in high-risk zones, whereas dangerous sites may exist in low-risk zones.

Following is a list of the characteristics that are essential to site safety.

Checklist for evaluation of the safety of your site

1. Site elevation is above anticipated storm-surge level (table 4.1).
2. Site is *behind* a natural protective barrier, such as a line of sand dunes.
3. Site is well away from any pass or position of former pass.
4. Site is in an area of shoreline growth (accretion) or low shoreline erosion. Evidence of an eroding shoreline includes (*a*) sand bluff or dune scarp at back of beach; (*b*) stumps or peat exposed on beach; (*c*) slumped features such as trees, dunes, or man-made structures; (*d*) protective devices such as seawalls, groins, or pumped sand.
5. Site is located in an area backed by salt marsh (for island or peninsular locations).
6. Site is away from low, narrow portions of land backed by water bodies.
7. Site is in an area of no or low historic overwash.
8. Site is in a vegetated area that suggests stability.
9. Site is well away from edge of bluff or escarpment.
10. Site drains water readily, even after heavy rain.

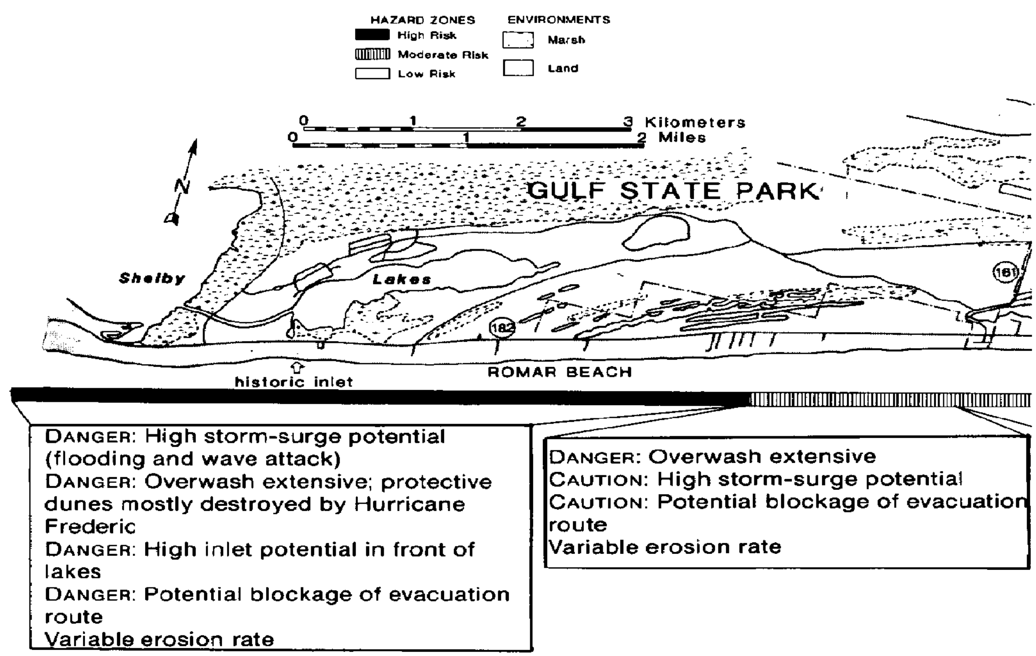
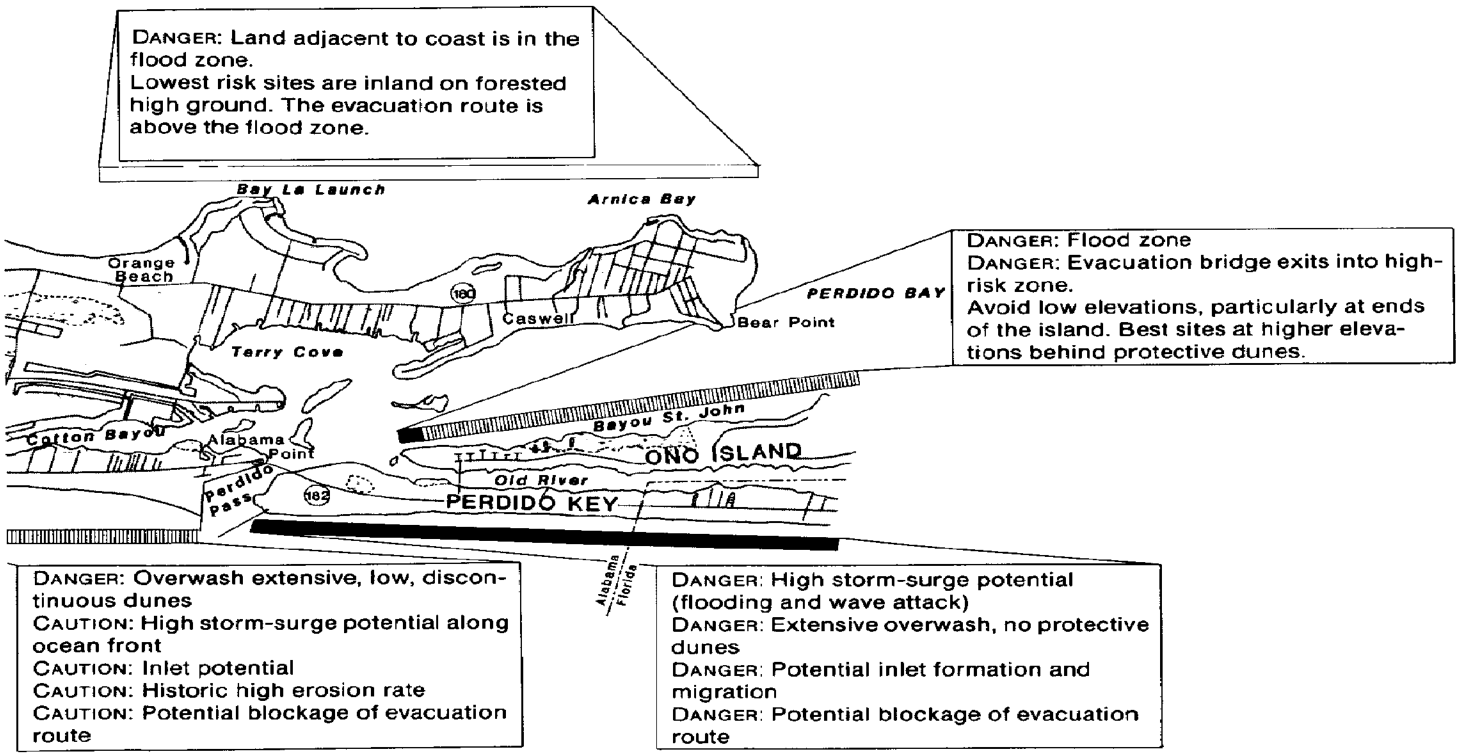


Fig. 4.6. Site analysis: Perdido Key to Shelby Lakes.


DANGER: Land adjacent to coast is in the flood zone.
Lowest risk sites are inland on forested high ground. The evacuation route is above the flood zone.
Bay La Launch
Arnica Bay
Orange Beach
180
Caswell
Bear Point
PERDIDO BAY
Terry Cove
Cotton Bayou
Alabama Point
Perdido Pass
182
Bayou St. John
ONO ISLAND
Old River
PERDIDO KEY
Alabama
Florida
DANGER: Flood zone
DANGER: Evacuation bridge exits into high-risk zone.
Avoid low elevations, particularly at ends of the island. Best sites at higher elevations behind protective dunes.
DANGER: Overwash extensive, low, discontinuous dunes
CAUTION: High storm-surge potential along ocean front
CAUTION: Inlet potential
CAUTION: Historic high erosion rate
CAUTION: Potential blockage of evacuation route
DANGER: High storm-surge potential (flooding and wave attack)
DANGER: Extensive overwash, no protective dunes
DANGER: Potential inlet formation and migration
DANGER: Potential blockage of evacuation route

11. Fresh groundwater supply is adequate and uncontaminated. There is proper spacing between water wells and septic systems.
12. Soil and elevation are suitable for efficient septic tank operation.
13. No compactable layers such as peat are present in the soil below building footings. Site is not on a buried salt marsh.
14. Adjacent structures are adequately spaced and of sound construction.

Escape routes

Because of the threat of hurricanes, there must be a route that will permit escape from any low-lying coastal area to a safe location inland within a reasonably short time. The presence of a ready escape route near your building site is essential to site safety, especially in high-risk areas where the number of people to be evacuated, transported, and housed elsewhere is large.

Select an escape route ahead of time

Check to see if any part of a potential escape route is at a low elevation, subject to blockage by overwash or flooding; if so, seek an alternate route. Several exit routes from Gulf Coast low-lying areas are flood-prone. Note whether there are bridges along the route. Remember that some residents will be evacuating pleasure boats, and that fishing boats will be seeking safer waters; thus, drawbridges will be accommodating both boats and automobiles. Assume that the electricity will be cut off, perhaps when the bridge is in the up position! Periodically reevaluate the escape route you have chosen—especially if the area in which you live has grown. With more people using the route, it may not be as satisfactory as you once thought it was (see Hurricane information, appendix B).

Use the escape route early

Be aware that some coastal areas have only 1 route for escape to higher elevations. In the event of a hurricane warning, evacuate immediately; do not wait until the route is blocked or flooded. Anyone who has experienced the evacuation of a community knows of the chaos at bottlenecks. Depend on it: excited drivers will cause wrecks, run out of gas, have flat tires, and cars of frightened occupants will be lined up for miles behind them. Be sure to have plans made for where you will go. Keep alternative destinations in mind in case you find the original refuge filled or in danger.

Hurricane Carmen, which hit the Gulf Coast in September 1974, illustrated the desirability of leaving early to miss the traffic jam. More than 75,000 people are said to have evacuated from what were thought to be the danger areas in Louisiana and Mississippi. The traffic was bumper-to-bumper on the few roads leading north. One accident backed up traffic for 19 miles. Motel lobbies were filled with people looking for a place to stay; all rooms were taken. Weary people were forced to continue traveling north until they found available space. Also keep in mind that hurricane-force winds and heavy rainfall will extend far inland. Hurricane Frederic in 1979 generated 75-mph winds at Meridian, Mississippi, and together with torrential rain made driving difficult for those coming inland from the coast. The continued population growth in the coastal zone of Alabama and Mississippi has only compounded the evacuation problem.

Individual area analysis: high-, moderate-, and low-risk zones

The Mississippi-Alabama coastal zone is a complex of different environments, each with its own set of conditions and problems. We have divided the area into a number of smaller units to facilitate discussion.

Alabama

Baldwin County

Diversity characterizes the Baldwin County coast with more than 30 miles of ocean Gulf shoreline, and many times that length of shore again in Mobile Bay, Bon Secour Bay, Wolf Bay, Perdido Bay, Bayou St. John, Old River, and the many smaller bays and bayous. Because of shoreline diversity the county is subdivided into 3 major sections to simplify this discussion. The first area is Perdido Key, Ono Island, and the Orange Beach–Caswell–Bear Point area. The second area is the Gulf Coast west of Perdido Pass to Mobile Point at the end of the Fort Morgan Peninsula, including Gulf Shores, Gulf Highlands, and the peninsula's bay side. The third area of the county to be examined is the eastern shore of Mobile Bay, including the shores of Bon Secour Bay north of the Bon Secour River.

Perdido Bay area

Perdido Key. As shown in figure 4.6, Perdido Key is a high-risk zone. The area is a good example of barrier coast facing a multitude of natural hazards, and one that is totally unsuited for development for the following reasons. (1) Except for areas immediately adjacent to Alabama Highway 182, the Alabama portion of the key is low in elevation (slightly above 10 feet). Hurricane Frederic totally flooded most of the key with high-water marks reaching 9 to 14 feet above sea level. (2) Sand dunes are poorly developed and sparsely vegetated. Many of the dunes are active, and the area is characterized by blowing sand. Hurricane Frederic's storm surge and waves swirled over the key, washing the highway out in several places and damaging the few houses that were in the area. (3) Overwash has been extensive. (4) The potential exists for erosion, flooding, and inlet formation to occur from the landward side of the key. Perdido Pass is an engineered inlet, no longer able to widen or "blow-out" in response to a big hurricane. These waters are likely to seek a new route to the sea during flooding by forming a new inlet. (5) These last 3 hazards may preclude evacuation on Highway 182, the only escape route. (6) Erosion data show mixed results; this beach is sometimes eroding, sometimes building up, but net erosion is expected over the intermediate term because of the rising sea level. Sand trapping due to the breakwater cannot be regarded as the pattern for the entire key.

In 1983 construction began on condominiums in this area (fig. 4.7; see chapter 5 for a review of the controversy). Construction leveled dunes, and buildings are being located precariously close to the shoreline. Destruction will be severe for this area, even in

Fig. 4.7. Condominium construction on Perdido Key, 1984. Compare to Figures 4.8 and 5.2. Note absence of dunes and positioning of building at back edge of beach. Photo by Eugene Brannan, Freelance Photography Unlimited, © 1984.

the next moderate hurricane to make local landfall. The Florida section of Perdido Key has a few areas of higher ground (locations not flooded by Frederic), but in general it suffered the same type of destruction as the western portion during Hurricane Frederic.

Ono Island. This island owes its "island" character to the work of man. At one time this strip of land was connected to the Alabama mainland, but between 1867 and 1892 the local residents excavated a channel through the western end of the peninsula. The connection of Perdido Bay directly to Perdido Pass via Bayou St. John reduced the flow through Old River and contributed to later changes in Perdido Pass (fig. 3.3). Ono Island's low western end also has undergone some changes in shoreline position. The island's position landward of Perdido Key affords protection from direct storm surge and wave attack, but farther west in the Gulf Shores area cottages on the north side of Little Lagoon suffered considerable damage or destruction during Hurricane Frederic in spite of a similar "protected" position.

Those central portions of the island with higher elevations on vegetated dune ridges are suitable for limited development. Therefore, Ono Island can be looked on with caution, particularly in view of the single escape route's exit onto Perdido key (fig. 4.8), a high-hazard zone. As development on Perdido key increases, Ono Island's evacuation problem worsens. In addition, water supply may be a problem. During the summer of 1984 the island experienced a water shortage and sewer difficulties.

Orange Beach–Caswell–Bear Point. The peninsula that lies between Bay La Launch–Arnica Bay and Terry Cove–Bayou St. John is an example of a more protected area in the coastal zone that is suitable in part for development. Shoreline property along Terry Cove is flood-prone, as is water-front property west of Orange Beach at the south end of Wolf Bay. For example, Frederic's flood level approached 8 feet along the south shore. Low-risk sites are in the central portion of the peninsula where elevations are on the order of 20 feet. Keep in mind that structures at higher elevations are still vulnerable to hurricane winds, and in the event of a hurricane early evacuation may be warranted. High ground with good vistas plus proximity to water access and a short drive to the beaches make this a prime area for consideration.

Cotton Bayou (North Shore). The point of land between Cotton Bayou and Terry Cove is a low-lying, marshy area that has been filled and partially developed. The entire area was flooded during Hurricane Frederic and will be flooded in the future. Finger canals dredged to provide more property with water access have enhanced this likelihood, as well as creating the potential for other water quality problems. Although the area is protected from the open Gulf, it should be regarded as a moderate-risk zone. Owners of existing structures should consider improving the structural integrity of their buildings (see chapter 6).

Gulf beaches (Perdido Pass to West Beach)

Gulf beaches, south of Cotton Bayou. The peninsula from Perdido Pass (Alabama Point) to the area near the junction of Alabama Highways 182 and 161 is developed on the Gulf side and in the vicinity of the pass. The east end, adjacent to Perdido Pass, historically is an area of rapid shoreline erosion (greater than 10 feet a year; reference 58, appendix C). However, the stabilization of the inlet with the construction of the seawall / breakwater in the 1960s altered this pattern. Fill in back of the breakwater and some accretion to the west widened the area near the jetty; however, all of the land in front of Cotton Bayou should be viewed as a moderate-risk zone. Therefore, all development in the area should be approached with caution.

As a general guideline in looking for the safest sites, the land located in the central part of the peninsula, near the highway, at the higher elevations behind the dunes is best, assuming prudent construction practices are followed. For the most part, this area is

Fig. 4.8. Ono Island and bridge onto Perdido Key in 1981 prior to development on the key. Ono Island's relative low-risk sites on vegetated high ground behind dunes stand in sharp contrast to the high-risk sites of the low, nearly featureless key that faces the open Gulf. Note the low elevation of the escape route. Residents should evacuate early in the face of a hurricane threat. Photo by Bill Neal.

landward of the line of pre-Frederic cottages that were not flooded in that storm but that lost protective dune elevation between them and the Gulf. Although stable and vegetated dunes exist along the beach front, they are generally low and offer no protection to the cottages built between the dunes and the Gulf of Mexico! Access roads and driveways that cut through dunes create potential sites for overwash during storms.

Shorefront property should be avoided. A moderate hurricane making a landfall west of this area will cause damage or destruction to property even in the most ideal sites within this zone. The newer condominiums and a hotel scheduled for construction in 1984 lie in Frederic's storm-surge zone. Unfortunately, the primary dune line as defined for the setback requirement was severely eroded during Hurricane Frederic, and overwash was extensive. New structures that satisfy the setback requirement, but that in fact lack the intended natural protection of a well-developed dune line, are facing high risk. Such development actually adds to the threat that exists for its neighbors, especially when dunes have been leveled during construction. Not surprisingly, some of the original residents in this area refer to these development methods as "rape and run"—strong terms that reflect the opinion that the developers will be gone, leaving new owners and their neighbors to suffer the consequences. The lesson is to know the ownership of adjacent properties, their likely future, and how rigorous state regulations and building codes will be interpreted and enforced, or be ready to do legal battle (not what you came to the beach to enjoy).

The low-lying shore along Cotton Bayou is subject to flooding. Again, the higher elevations are adjacent to the highway.

The area east of Romar Beach is also classified as a moderate-risk zone (fig. 4.6); however, it is somewhat more stable than the peninsula.

Romar Beach–Shelby Lakes area. Beach-front sites are dangerous. Figure 4.6 indicates the increasing risk due to coastal hazards westward from the junction of Highways 161 and 182 to west of Romar Beach. Much of the area inland from the beach is part of Gulf State Park and is either marsh or very low in elevation. West from the junction for a distance of approximately 2.3 miles, this mainland coast has dunes that locally reach elevations greater than 12 feet. Sites at these higher elevations near the highway, and where there are protective dunes between the site and the beach front, may be regarded as being in the moderate-risk category (fig. 4.9). For instance, Frederic's flood level was in excess of 15 feet above mean low water at some points in this area.

Continuing through Romar Beach to the eastern beach boundary of the state park, Frederic's storm surge eroded away the dunes that formerly offered some protection from storm waves. Flood levels were near 17 feet, and wave runup brought water to elevations of nearly 24 feet above mean low water level, one of the highest for Frederic. Flooding and overwash extended into the low areas north of the highway. Dunes near the water were totally destroyed; others were extensively reduced in elevation. Until the washed-out dunes rebuild, this entire low-lying area is highly vulnerable to wave attack and overwash associated with future storms.

Fig. 4.9. Romar Beach area illustrating contrasting site safety. Front row of cottages lacks natural protection. Owners are attempting to establish sand dunes through the use of sand fences. Cottages in second row have good setback, are on higher ground, and have some natural protection in the form of dunes and vegetation. Note access roads that cut through the dunes. These are likely to become overwash passes during a hurricane. Photo by Bill Neal.

If Hurricane Frederic had made its landfall a few miles farther east, this area would have experienced the same devastation that occurred in Gulf Shores.

The area included in Gulf State Park south of the Shelby Lakes is vulnerable to inlet formation, flooding, and overwash (figs. 4.6 and 4.10). Fortunately, this high-risk area is available for public recreation without extensive development. Unfortunately, the convention center and adjoining lodging facilities were constructed in the high-risk zone. Subsequently, Hurricane Frederic proved the high-risk nature of the site. Currently, protective dune growth is being engineered in front of the facilities.

The narrow strip of sand that separates west Shelby Lake from the Gulf was an inlet at some time in the past. The situation is like east Shelby Lake, which was connected to the Gulf by an inlet in historic times; this water connection was reopened temporarily during Hurricane Frederic. This opening was closed in mid-September of 1979 to prevent saltwater mixing with the freshwaters of Shelby Lakes.

Gulf Shores area. The community of Gulf Shores stands as a classic example of how coastal development in a high-risk zone originates, evolves, and responds to storm impact. Prior to World War II the seed of this development was a single row of beach cottages owing their location to the fact that it was the end of the road. The Sibley Holmes Trail, Alabama Highway 59, was the access. Highway 182 was a later catalyst for lateral growth. When beach-front real estate came into shorter supply, the marsh was developed. The dredge spoil from finger canals was the fill to make

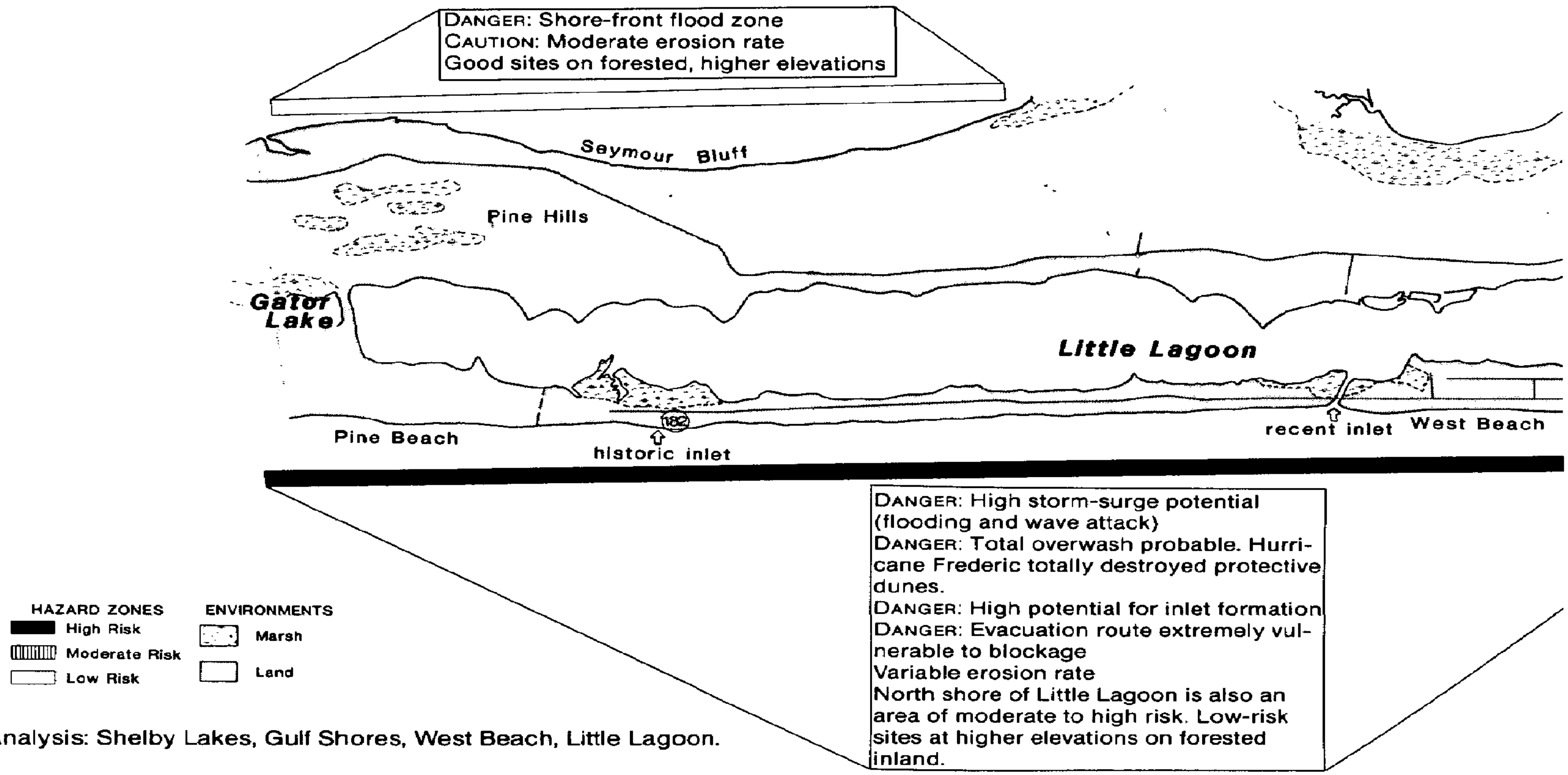
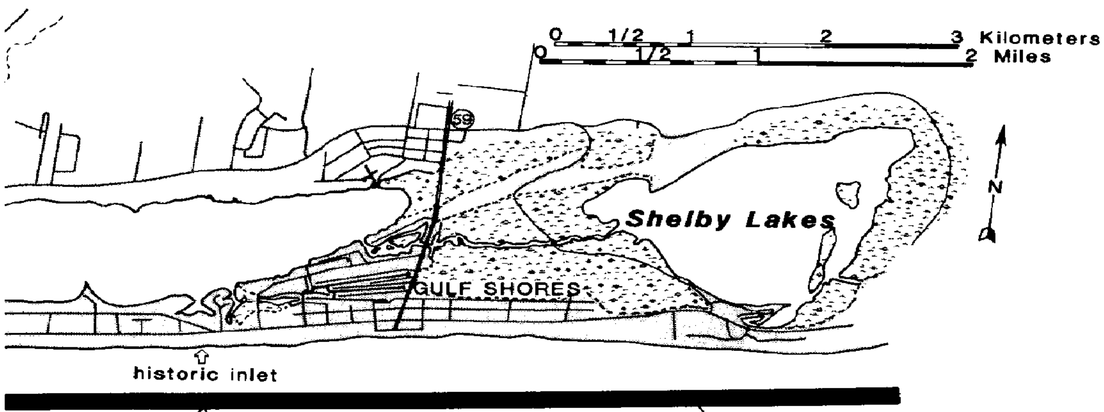


Fig. 4.10. Site Analysis: Shelby Lakes, Gulf Shores, West Beach, Little Lagoon.



DANGER: Storm-surge flood zone
DANGER: Overwash potential, no protective dunes
DANGER: Evacuation route in flood zone
CAUTION: Beach-front property is in potential storm-wave zone.
Low inlet potential.
North side of development in moderate-risk zone.

wetland dry while providing more waterfront property. Occasional storms did not deter development. Camille, which generated flood levels of 6 to 9 feet above mean low water, was not taken as a harbinger of what might happen here 10 years later.

The development illustrates the folly of building in unprotected, high-hazard coastal areas (fig. 4.10). Hurricane Frederic devastated Gulf Shores. Highway 182 was buried by sand or washed out in several places. Nearly every cottage and building suffered destruction or heavy damage. The tally was 80 percent (400) of the cottages destroyed and another 6 percent (21) of the cottages so severely damaged that the residents had to seek alternative shelter.

The area is very low in elevation, including the poorly developed dunes that existed prior to Hurricane Frederic. The pre-hurricane maps show the discontinuity of the dunes and susceptibility to overwash. Many of the dunes had lost their stabilizing cover of vegetation due to human activity. Few dunes survived the storm. Flood level reached 11 to 12 feet above mean low water, both along the beach front and in the back marsh area. On top of the storm surge, waves battered the structures. The entire community was flooded.

Frederic was not the last chapter in Gulf Shores storm history. The next storm will find the community more vulnerable because the protective dunes are gone and the sand reservoir depleted. Future storms will be more costly because cottages are being replaced by condominiums (fig. 4.11). Although the experience of Frederic has increased precaution, the bravado to build the com-

Fig. 4.11. Post-Frederic construction in the Gulf Shores area. Note complete absence of primary dunes and location of multi-unit construction at the edge of the narrow beach. Pilings at left are for a similar unit, increasing the density of development in this high-risk zone. This area was completely flooded by Hurricane Frederic, and all of the area between the beach and road was overwashed. Photo by Bill Neal.

munity back "bigger and better" than before has not lessened the risks from the now well-known hazards.

Federal attempts to control development through restrictions on a new sewer system did not meet with local acceptance. The system was financed without federal aid, thereby avoiding growth restrictions. While this action is commendable from the point of view that the community is not relying on a federal subsidy, it will allow for greater growth. As the size of the investment grows, pressure will develop to protect that investment. By way of prediction, that pressure will come in the disguise of a movement to protect the beach (which, incidentally, still existed after Frederic).

Gulf Shores - West Beach. The area separating Little Lagoon from the Gulf responds to storms in the same way as a narrow barrier island (fig. 4.10). Highly susceptible to erosion from flooding and overwash, it is unstable and unsuited for development. The narrow, low sections also may be cut by new inlets like those that have formed in the past (fig. 4.12). The destruction from Frederic

Fig. 4.12. Area between Gulf Shores and inlet into Little Lagoon. The unvegetated white sand area is the overwash deposit of Hurricane Frederic. The cottages are post-hurricane occupation of a high-risk velocity zone. During storms the inlet may shift laterally, or a new inlet may form across the barrier between the Gulf and the lagoon. Photo by Bill Neal.

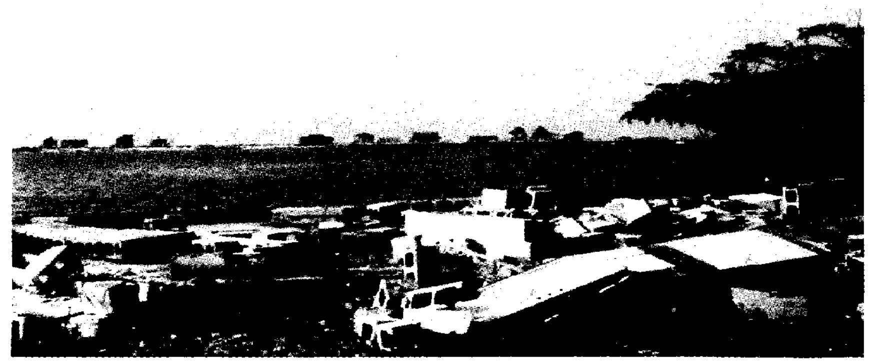
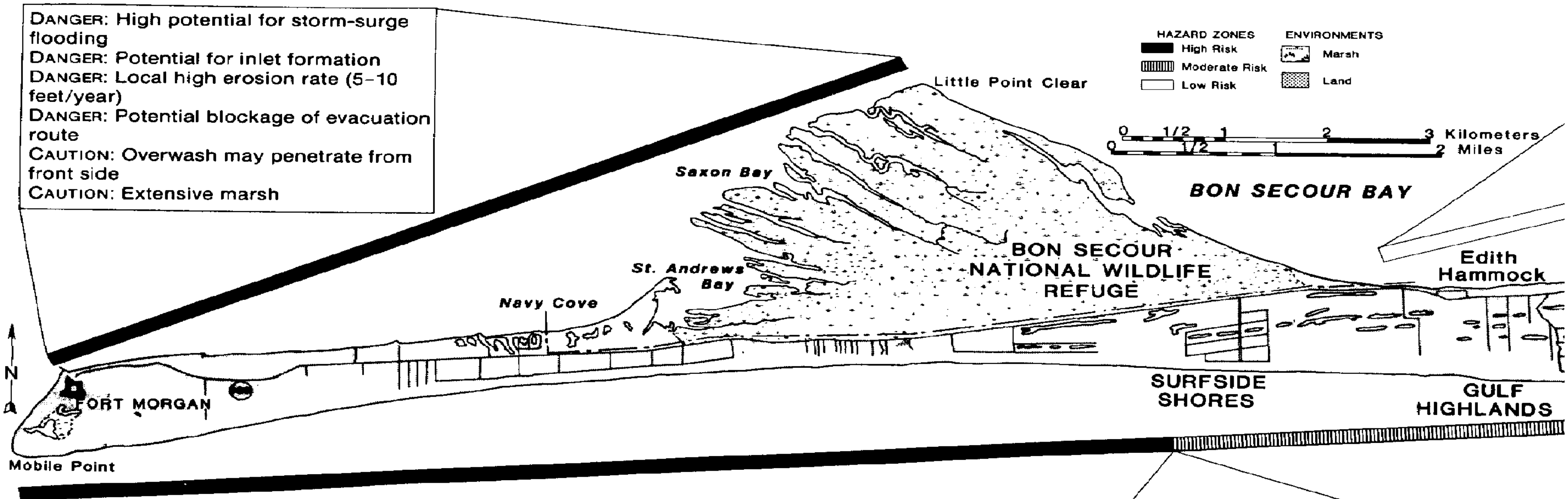


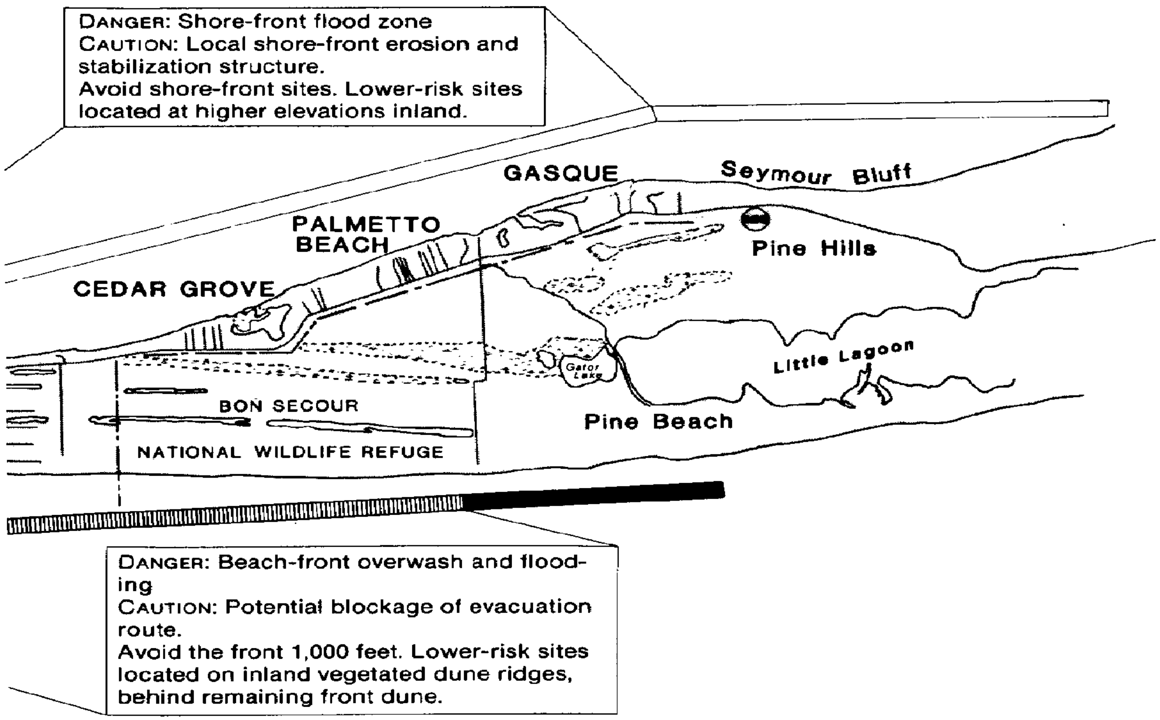
Fig. 4.13. Rubble of cinder block cottage on north shore of Little Lagoon. Note cottages on the low barrier in the background, looking toward the Gulf across Little Lagoon. Photo by Bill Neal.

DANGER: High potential for storm-surge flooding
DANGER: Potential for inlet formation
DANGER: Local high erosion rate (5–10 feet/year)
DANGER: Potential blockage of evacuation route
CAUTION: Overwash may penetrate from front side
CAUTION: Extensive marsh



DANGER: High potential for storm-surge flooding and wave attack
DANGER: Extensive overwash zone; Hurri cane Frederic washed away protective dunes
DANGER: Moderate potential for inlet formation, western half
DANGER: Evacuation route likely to be blocked during storm
CAUTION: Local problems with erosion and water supply are likely

Fig. 4.14. Site analysis: Fort Morgan Peninsula (Little Lagoon to Mobile Point; Mobile Bay and Bon Secour Bay).


DANGER: Shore-front flood zone
CAUTION: Local shore-front erosion and stabilization structure.
Avoid shore-front sites. Lower-risk sites located at higher elevations inland.
GASQUE
Seymour Bluff
PALMETTO BEACH
CEDAR GROVE
Pine Hills
Little Lagoon
Pine Beach
BON SECOUR
NATIONAL WILDLIFE REFUGE
DANGER: Beach-front overwash and flooding
CAUTION: Potential blockage of evacuation route.
Avoid the front 1,000 feet. Lower-risk sites located on inland vegetated dune ridges, behind remaining front dune.

as described above included this area. The hurricane's wind and storm surge also destroyed a large number of cottages on the north shore of Little Lagoon (fig. 4.13). Do not locate in this area unless you are willing to take the risk. Residents in this zone should evacuate early in the case of a storm warning.

Fort Morgan Peninsula

Figure 4.14 classifies both the Gulf and bay sides of the peninsula. With the exception of local areas of high ground in Gulf Highlands, most of the area is in a high-hazard zone. The Gulf side has experienced shoreline erosion, and moderate hurricanes flood and overwash much of the area. The potential for new inlets also exists.

Gulf Highlands–Surfside Shores. A series of east-west arcuate dunes ridges, curving slightly to the north, extend for a distance of 4 to 5 miles along the peninsula. These ridges may represent a remnant of an old barrier island. Elevations along some crests are in excess of 20 feet. The eastern portion of the ridge complex consists of sharply defined ridges separated by wide, low areas, sometimes wetlands. This extension of the upland is part of a wildlife refuge and contains very few sites suitable for development.

To the west, the sand ridges merge into a more continuous up-

To the west, the sand ridges merge into a more continuous upland that includes the residential development. Individual sites vary in relative safety, and even the best locations have a moderate risk. Frederic's floodwaters penetrated the frontal 800 to 1,000 feet of shore front, and cottages in this zone were destroyed or

Fig. 4.15. Building sites at Surfside Shores laid out on the back of the beach in 1980. Although formerly a line of dunes, Hurricane Frederic reclassified this land as beach in 1979. Dynamic equilibrium says it will be beach again! Photo by Bill Neal.

Fig. 4.16. Row of beach-front cottages at Surfside Shores facing the Gulf without protection. Previous hurricanes have wiped this area clean, destroying dunes and earlier cottages. Stumps exposed on beach are evidence of shoreline erosion. Photo by Bill Neal.

heavily damaged. Even if a high, continuous frontal dune had been present before the storm, the area would not have escaped damage. Recorded flood levels varied between 10.1 and 13.6 feet above mean low water, existing sand dunes were leveled or heavily eroded, and even cottages on higher ground were damaged or destroyed by the brunt of Frederic's forces. Like Gulf Shores, the Gulf Highlands and Surfside Shores developments illustrate the temporary nature of human intrusion into such a dynamic zone. Such development is truly at Mother Nature's mercy.

In the rush to rebuild after Frederic, the now-absent protective dunes and vegetation were ignored. Builders bulldozed sand onto the back of the beach to create building sites (fig. 4.15) in the high-hazard zone. Many structures were built seaward of the post-storm dune line (fig. 4.16) and are in jeopardy from future storms and shoreline retreat.

If you must locate in these developments, choose a site on one of the well-vegetated dune ridges, preferably above 15 feet in elevation. Locate behind the first vegetated dune ridge, at least 800 to 1,000 feet inland. Remember that storm surge is likely to flood all the way across the barrier to the bay. Debris from frontal cottages will act as battering rams against inland buildings unless they are above flood-wave level. Preserve the vegetation cover on your site to afford wind protection. In case of a hurricane warning, evacuate *early!* Low elevations along Highway 180 will flood, blocking escape.

West Surfside Shores to Mobile Point. From Surfside Shores to the tip of the Fort Morgan Peninsula is a high-risk zone (fig.

4.14). Storm-surge flooding, wave attack, erosion, and overwash brought widespread destruction to the area in 1979. Inlet formation during hurricanes is also a possibility. Most of Highway 180, the only evacuation route, lies in the flood zone, and portions of the road washed out or were buried during Hurricane Frederic. The only ground above flood level is in the vicinity of Fort Morgan, along with a narrow strip along the highway leading into the state park. Between Surfside Shores and Fort Morgan State Park several areas are being developed or redeveloped in the aftermath of storm destruction. As in the West Beach area where a line of dunes once offered some protection, the topography now is an unobstructed slope to the beach. If Frederic were to be repeated in this area today, the destruction would be greater than in 1979. New condominiums in part of this development only add to the problems of effective evacuation and provision of an adequate, high-quality water supply. Some of these structures have been in violation of ordinances (see chapter 5).

Bay Side (Palmetto Beach–Gasque to Fort Morgan). Low coastal sites in east Palmetto Beach are subject to flooding. Avoid sites located right on the shore, especially at elevations less than 7 or 8 feet. There are safer sites just inland with sufficient elevation to afford some protection. For example, south of the highway near Cedar Grove the land rises to above 15 feet. Edith Hammock is the backside of the barrier forming the Gulf Highlands and includes some protected sites, particularly the higher ridges south of the highway.

Living on the bay side of the peninsula is no guarantee that

Fig. 4.17. Hurricane Frederic's debris on bay side of Fort Morgan Peninsula. Cottages that remained intact floated into adjacent structures and into the bay in some cases. Photo by Bill Neal.

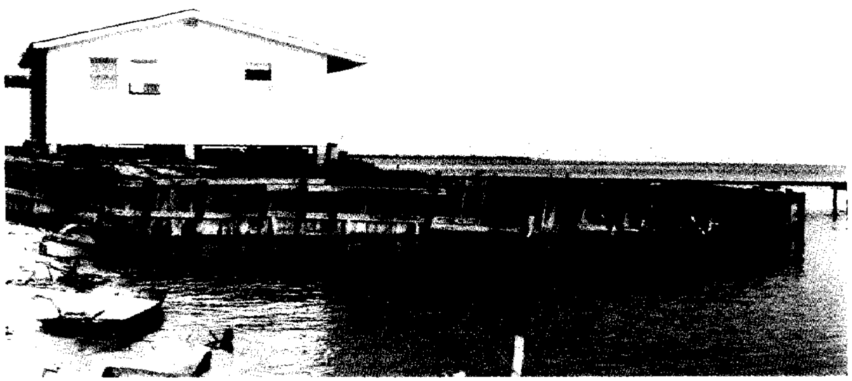


Fig. 4.18. Stumps and debris on beach are evidence of a retreating shoreline. The property owners must maintain the wooden bulkhead or their property will erode to the same position. The irregularity produced in the shoreline is likely to increase the rate of erosion for the adjacent property, leaving both properties more vulnerable to the next storm. Photo by Bill Neal.

your property will escape storm destruction. Examine not only your site, but the area between your property and the Gulf as well. Avoid low, narrow areas of the peninsula where floodwaters may attack from either direction (fig. 4.17). Much of the bay shore is eroding, so even if there were no hurricanes, shorefront property owners are faced with the added expense of trying to combat such erosion (fig. 4.18). These battles are lost to hurricanes; or, when persistent, strong winds out of the northwest generate destructive waves.

About 1 mile west of Edith Hammock an extensive marsh makes up Little Point Clear and extends to St. Andrews Bay. This area is part of the Bon Secour National Wildlife Refuge. Although a few forested sand ridges break up the marsh, Little Point Clear is not suitable for development. One would expect that a marsh would not be developed, even if it were not part of a protected area. This is not the case.

Less extensive tracts of marsh land to the west of St. Andrews Bay on the narrow peninsula have been dredged and filled for bay-side development. From St. Andrews Bay to Fort Morgan this development is in a very high-hazard zone based on just about every criteria that might be used to evaluate risk. Historic erosion rates for a significant part of this shore are from 5 to 10 feet per year. Storm-surge flooding affects the entire area, overwash may extend across from the front side, and new inlets may form. Numerous cottages along this Mobile Bay shore were destroyed or damaged by Hurricane Frederic. Between St. Andrews Bay and Fort Morgan State Park land is still available for purchase and development for those willing to take a very high risk.

Mobile Bay: eastern shore

Figures 4.14 through 4.23 characterize the hazards of the coastal margin along the east side of Mobile Bay and part of Bon Secour Bay. No risk classification is assigned in most of the figures, but the hazards are listed. Natural processes that threaten bay-front property tend to be fewer in number or of less magnitude than along the Gulf. Nevertheless, storm-surge flooding and hurricane winds pose a real danger along this bay shore. Hurricane Frederic caused extensive damage in the area. Locally, the only route for evacuation is in the flood zone (for example, around Bailey Creek).

Shoreline erosion also is a permanent problem. Hundreds of feet of shoreline retreat have been recorded in this century. Property owners have responded by building revetments and groins. From north of Weeks Bay to Fairhope the shoreline is a continuous hodgepodge of such structures (fig. 4.20). Beaches are absent except immediately south of Great Point Clear. When buying property, keep the following in mind. Revetments and groins are evidence of an erosion problem. You will have the additional cost of maintaining these structures. Such structures do not protect property from flooding. Know your evacuation route, and do not have a false sense of security because you live on the bay and not on the Gulf.

Bon Secour River to Gasque (Southeast Bon Secour Bay). A coastal marsh extends from the Bon Secour River to Seymour Bluff (figs. 4.14 and 4.19). This marsh zone is totally unsuited for development, although inland from the marsh the upland is sufficiently removed from the coast to be safe from flooding. Seymour Bluff, aptly

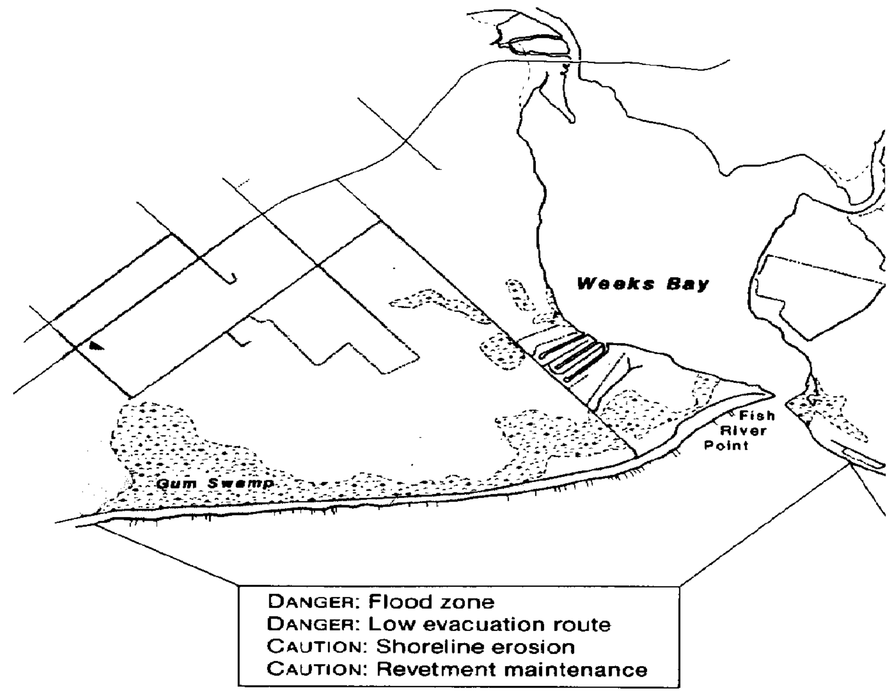
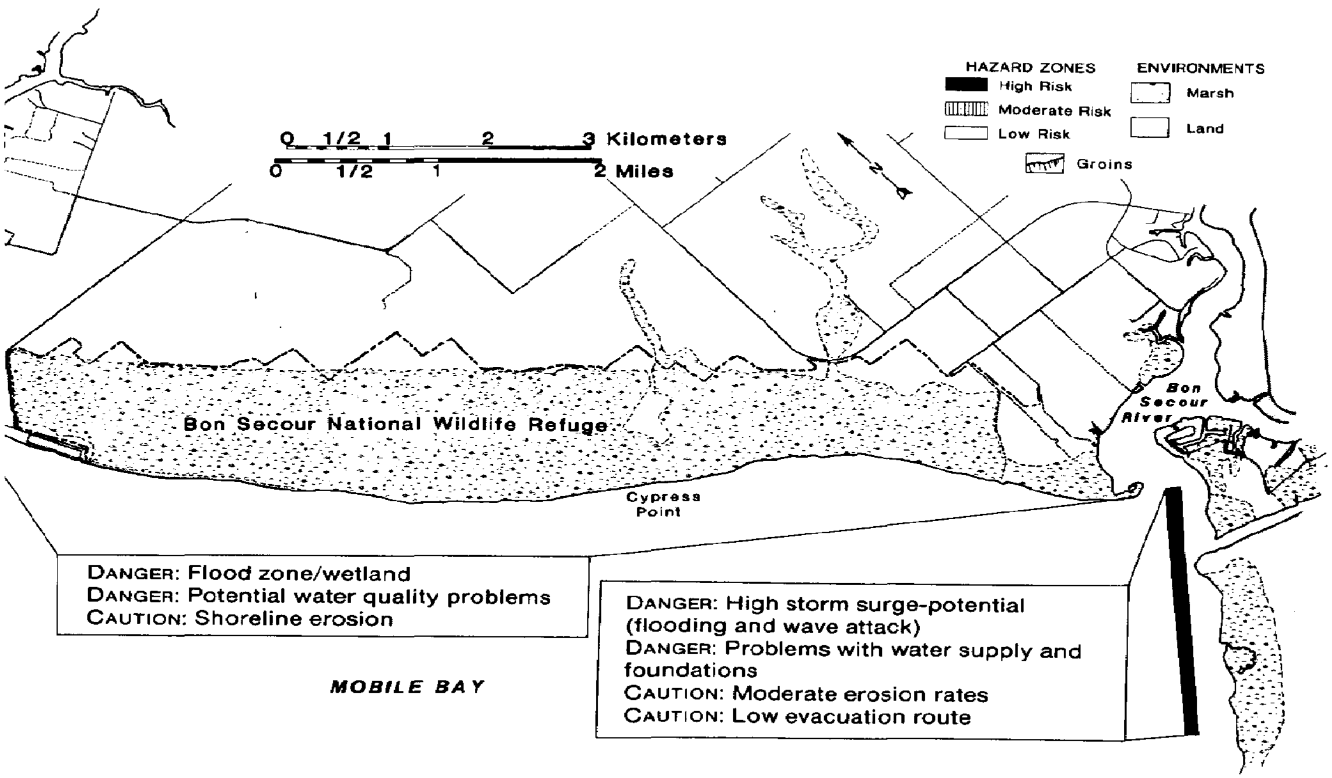


Fig. 4.19. Site analysis: Bon Secour Bay and Weeks Bay.


HAZARD ZONES
High Risk
Moderate Risk
Low Risk
Groins
ENVIRONMENTS
Marsh
Land
0 1/2 1 2 3 Kilometers
0 1/2 1 2 Miles
N
Bon Secour National Wildlife Refuge
Cypress Point
Bon Secour River
DANGER: Flood zone/wetland
DANGER: Potential water quality problems
CAUTION: Shoreline erosion
MOBILE BAY
DANGER: High storm surge-potential (flooding and wave attack)
DANGER: Problems with water supply and foundations
CAUTION: Moderate erosion rates
CAUTION: Low evacuation route

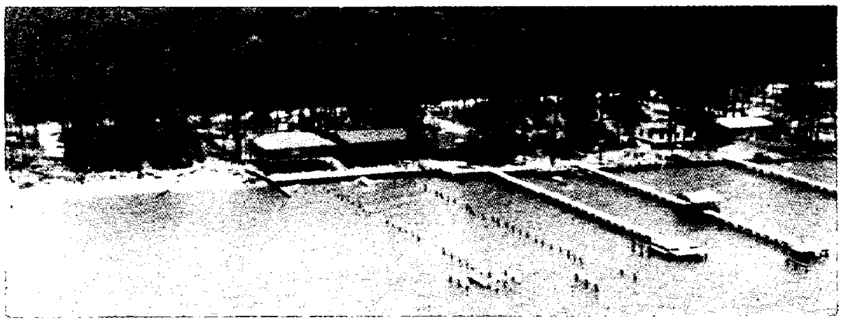


Fig. 4.20. The armored eastern shore of Mobile Bay. The high rate of shoreline erosion has led to property owners' constructing a hodgepodge of groins, bulkheads, and walls. Beaches and dunes are generally absent. Photo by Bill Neal.

named for its relatively high elevation along the south shore of Bon Secour Bay, parallels the bay to the community of Gasque. Sites located on the immediate shore front as at Gasque are in the flood zone as they discovered in 1979. Safer sites are to be found inland at the higher elevations, for example, south of Highway 180 east of Gasque and farther east in the vicinity of Miller Cemetery, north of the highway.

Sites along bluffs and wave-cut scarps should be avoided. Bluffs are semi-stable so the addition of a building or a simple activity such as watering the lawn can cause slope movement. Instead of the sea rising to claim the house, the house descends to meet the

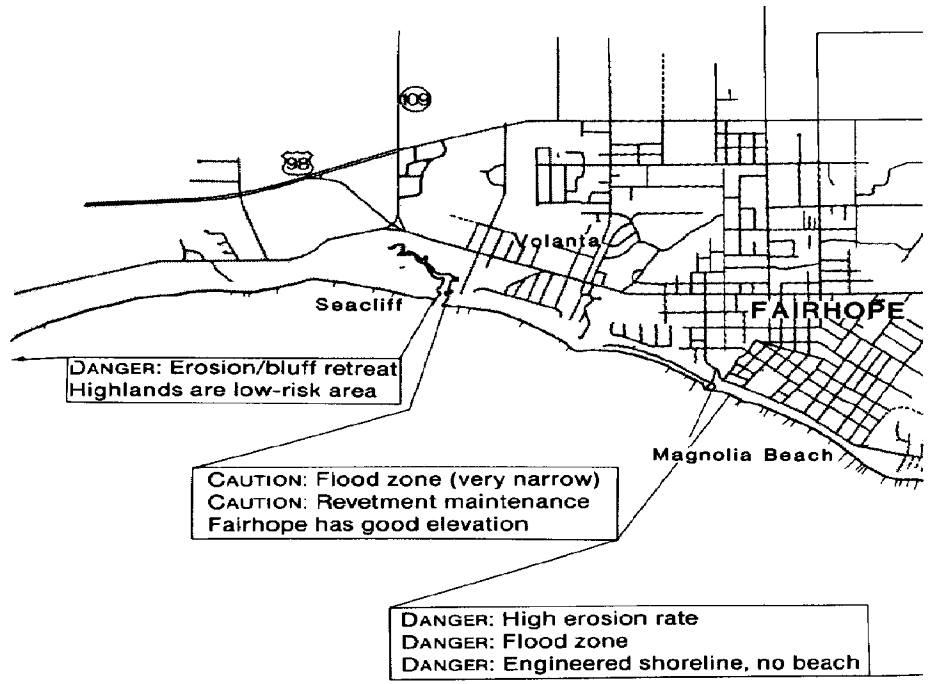
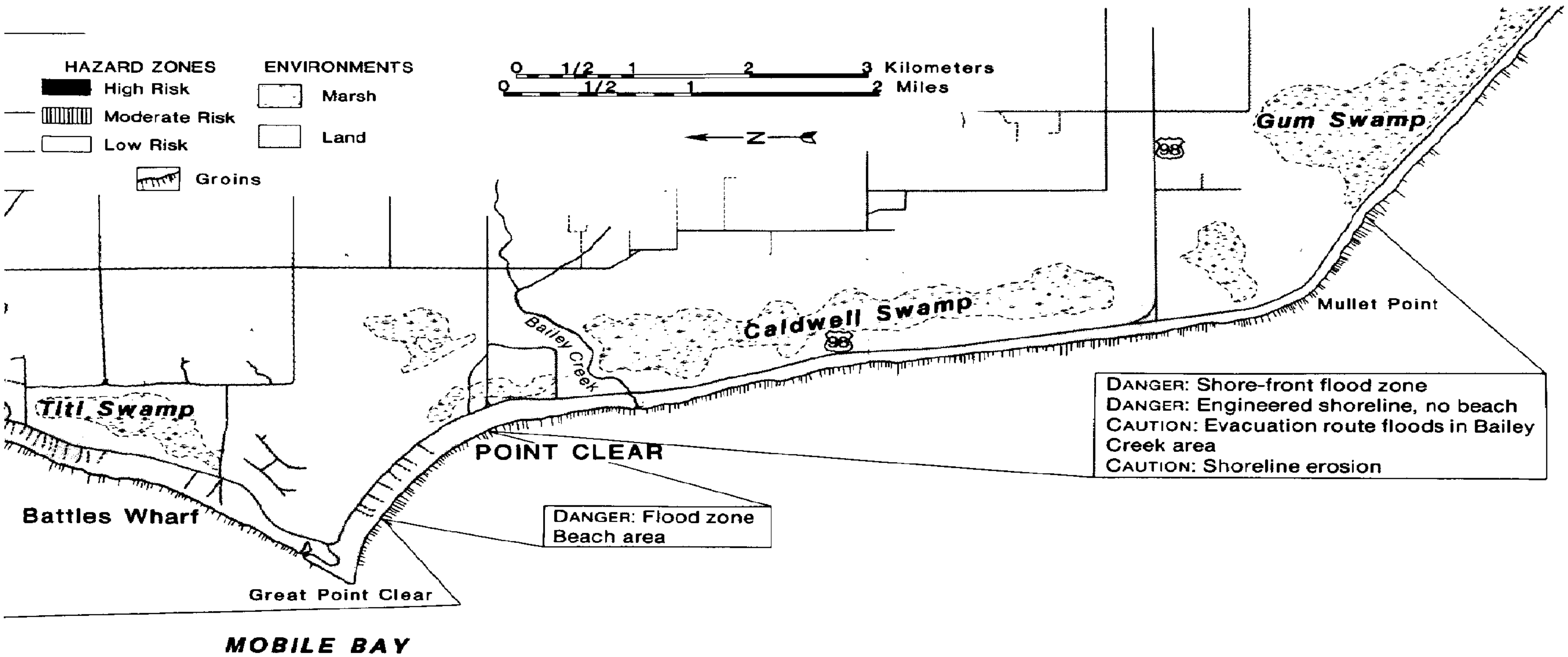


Fig. 4.21. Site analysis: Mobile Bay's eastern shore; Mullet Point to Fairhope.


HAZARD ZONES
High Risk
Moderate Risk
Low Risk
Groins
ENVIRONMENTS
Marsh
Land
0 1/2 1 2 3 Kilometers
0 1/2 1 2 Miles
N
Gum Swamp
98
Caldwell Swamp
98
Bailey Creek
Mullet Point
Titi Swamp
POINT CLEAR
DANGER: Shore-front flood zone
DANGER: Engineered shoreline, no beach
CAUTION: Evacuation route floods in Bailey Creek area
CAUTION: Shoreline erosion
Battles Wharf
DANGER: Flood zone
Beach area
Great Point Clear
MOBILE BAY

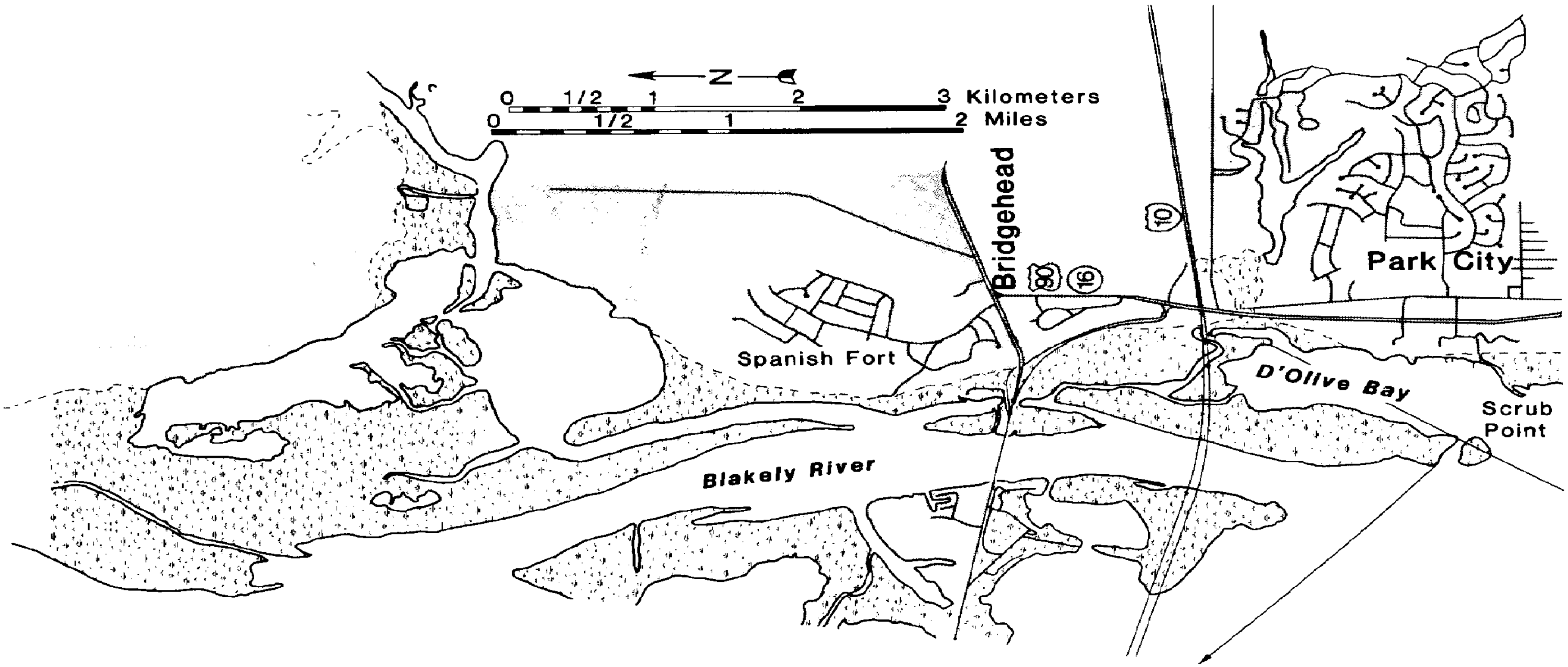
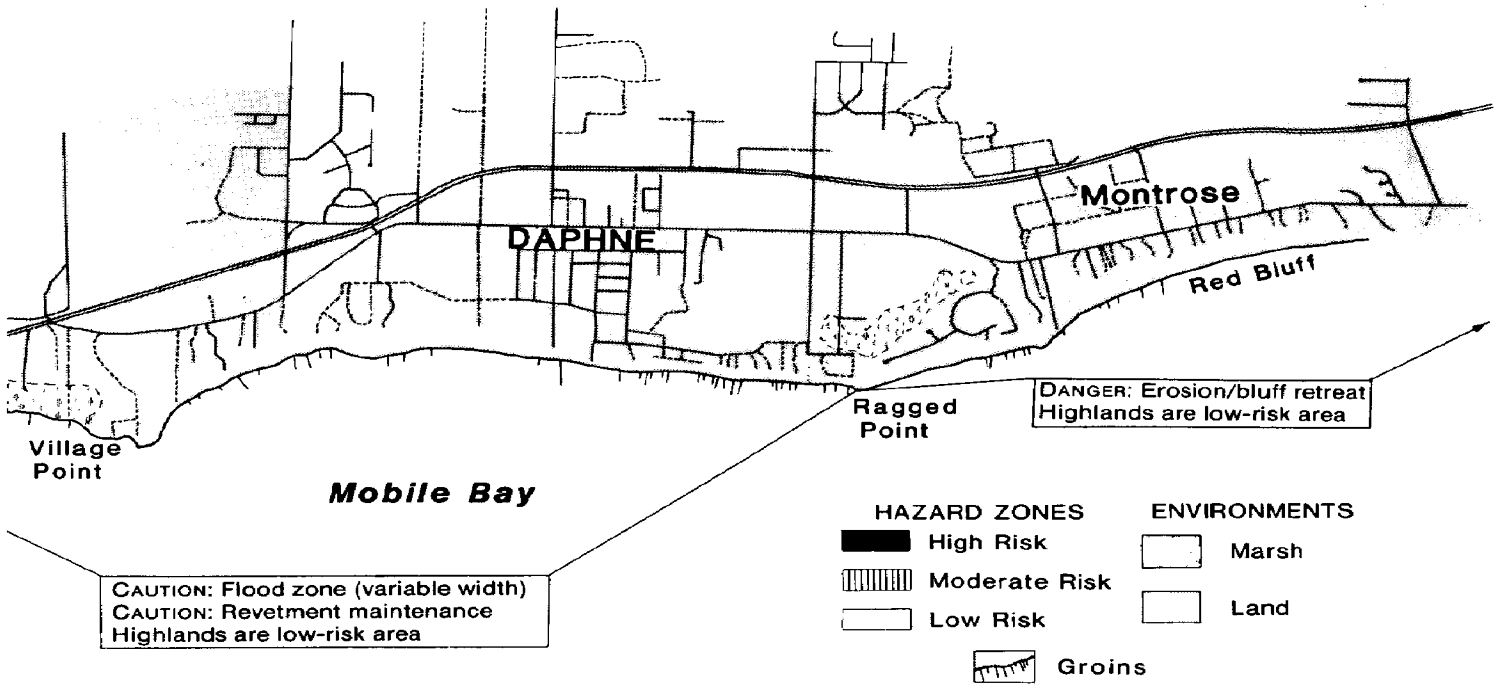


Fig. 4.22. Site analysis: Mobile Bay's eastern shore; Red Bluff to Bridgehead.


DAPHNE
Montrose
Red Bluff
Ragged Point
Village Point
Mobile Bay
DANGER: Erosion/bluff retreat
Highlands are low-risk area
CAUTION: Flood zone (variable width)
CAUTION: Revetment maintenance
Highlands are low-risk area
HAZARD ZONES
High Risk
Moderate Risk
Low Risk
ENVIRONMENTS
Marsh
Land
Groins

sea! In the area from the Bon Secour River to Catlin Bayou, erosion rates of 3 feet per year have been measured.

Bon Secour River to Fairhope. The flood zone is continuous from the Bon Secour River to Fairhope (figs. 4.19 and 4.21). South of Weeks Bay a wide area of marsh and swamp is subject to flooding. Most of this region is part of the Bon Secour National Wildlife Refuge, but the development south of Weeks Bay lies in the danger zone. North of Weeks Bay to Magnolia Beach in Fairhope the flood zone is usually narrow, extending inland to elevations of between 5 and 10 feet. Most of the cottages between the shore and Eastern Shore Boulevard lie within or at the edge of the flood zone. Many of these buildings, including the Grand Hotel on Great Point Clear, were damaged during Hurricane Frederic. Swamps (Gum, Caldwell, Titi) and creek floodplains inland of the coastal road also are subject to flooding.

Fairhope to Bridgehead. From Fairhope to Spanish Fort (fig. 4.22) at the head of the bay the shoreline is formed by the bluff edge of the upland. The cliffs or bluffs reach a height of 100 feet at Red Bluff and form a shoreline quite different from that south of Fairhope. Very little land is present between the base of the bluffs and the bay (fig. 4.23). These narrow strips are totally unsafe for development. Likewise, sites along the immediate edge of the sandy bluffs also should be avoided. Shoreline erosion at the base of the cliff, groundwater seepage from the bluff face, or loading of the upper edge of the bluff may trigger slumping or sliding. With time, the cliff edge will migrate inland as the erosion process continues. The price paid for the fantastic view from a bluff-edge house is likely to be a real-life cliff-hanger as in the old *Perils of Pauline*. The safest sites anywhere in the coastal zone are on these uplands, but well back from the edge!

Head-of-the-Bay. The delta complex at the head of the bay is made up of unstable marsh land, swamps, and shifting channels (fig. 4.24). Flooding may come from river runoff or coastal storms. The habitat provided by the delta make it an important natural resource, and it has been placed on the National Register of Natural Landmarks. With the possible exception of expendable hunting or fishing camps, the delta is unsuitable and unsafe for development. Frederic caused considerable damage to both the causeway and commercial buildings along the highway.

Fig. 4.23. Bluff shoreline. Waves erode base of bluff, causing slumping. Loading of bluff edge also causes slumping. Photo by Bill Neal.

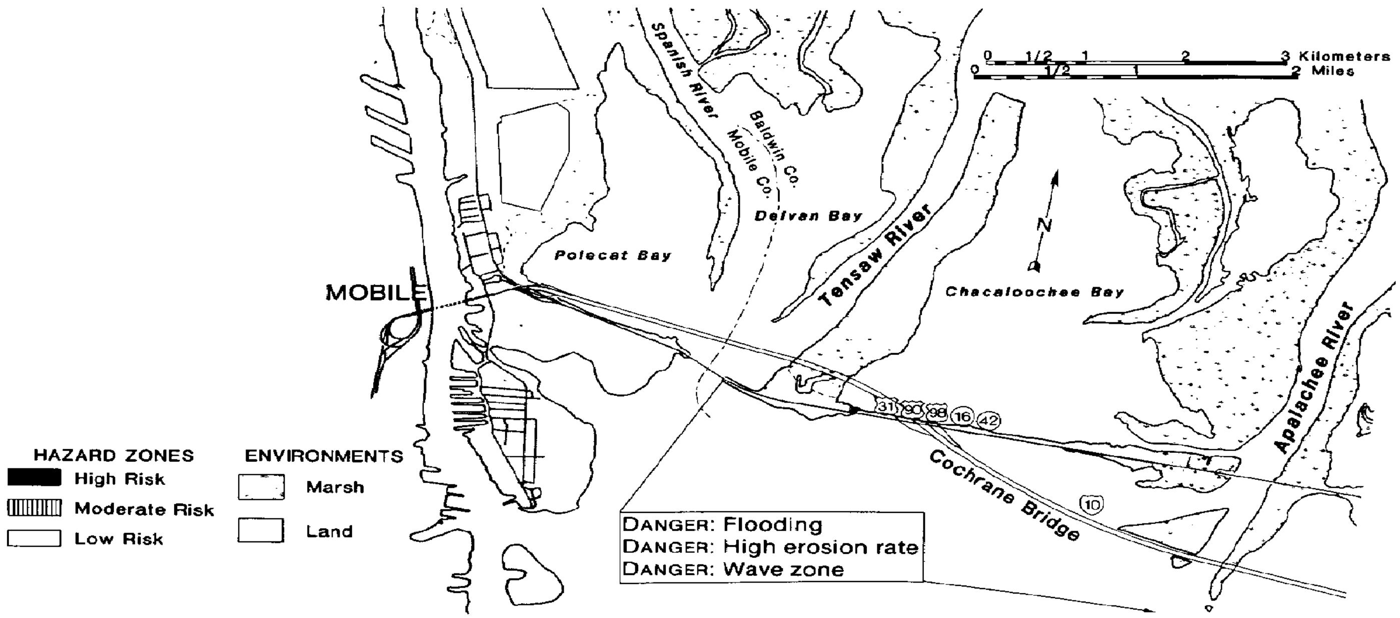


Fig. 4.24. Site analysis: Head-of-the-Bay.

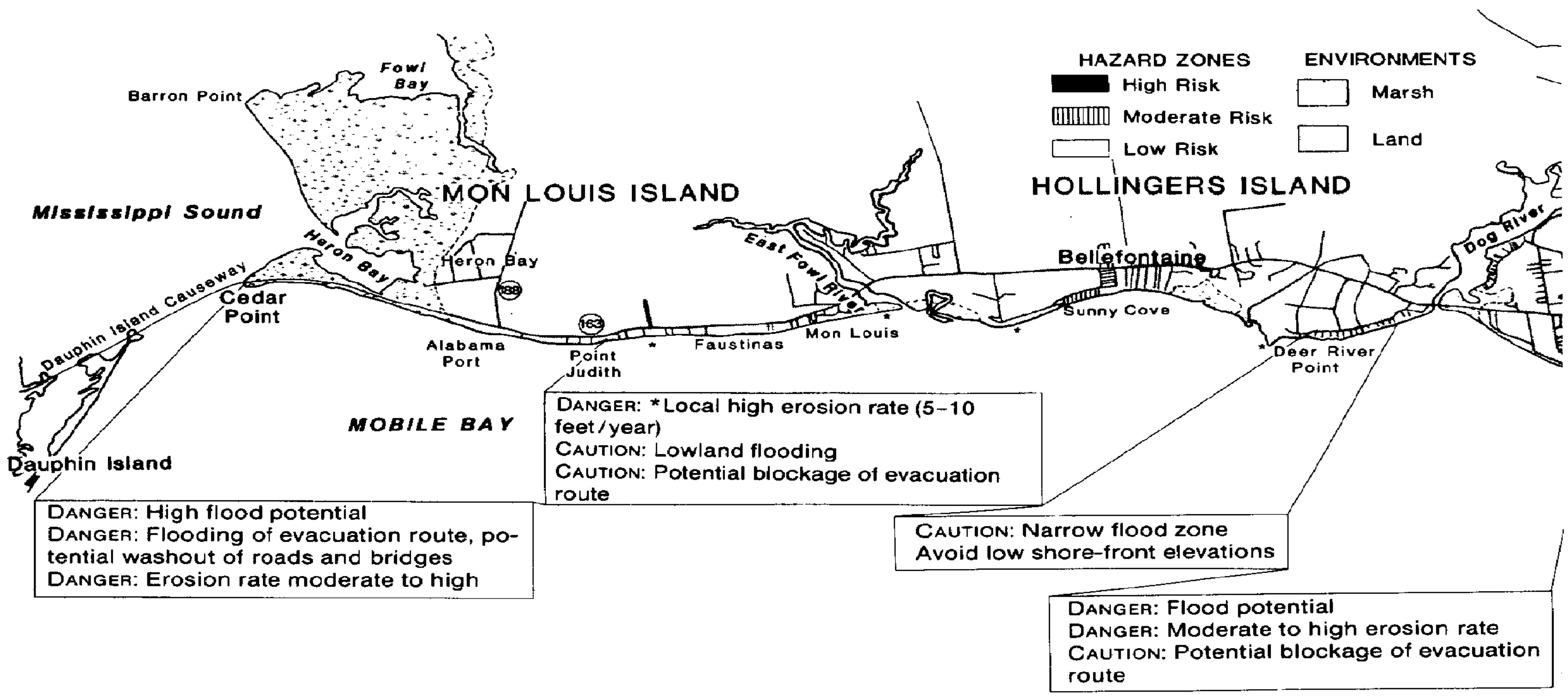
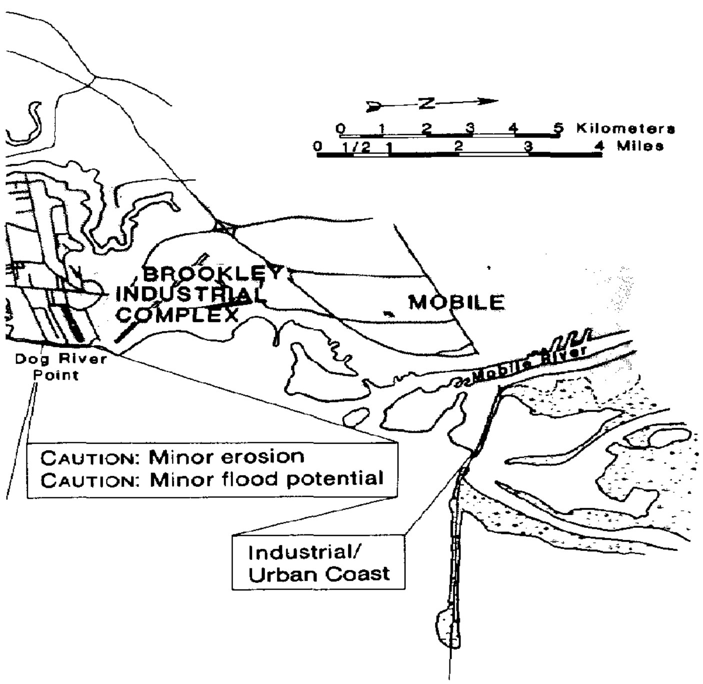


Fig. 4.25. Site analysis: Mobile Bay's western shore; Mobile to Dauphin Island Causeway.



Mobile County

As in Baldwin County, the diverse shoreline of Mobile County is subdivided for purposes of discussion. Four distinct areas can be defined, both in terms of general types of coast and human use. These include the Mobile urban shoreline, the western shore of Mobile Bay, the northern shore of Mississippi Sound, and Dauphin Island.

Mobile

The Mobile shoreline is a typical urbanized coast (fig. 4.25). From the mouth of Chickasaw Creek to the southern edge of the Brookley area the shoreline is either artificial or extensively modified. Large-scale dredge-and-fill operations were necessary for the Port of Mobile, associated facilities, the airbase, transportation corridors, and similar development. Much of McDuffie and Pinto islands is artificial land, built out of dredge spoil over the past century. Since 1917 over 1,600 acres of new land was added in the Mobile Harbor area, most of it constructed during the period of rapid development in the 1950s and 1960s.

Prior to the intense development of this coast, it was eroding. Studies indicate that before the early 1900s Choctaw Point and the shoreline south to Brookley were eroding. That old shoreline now lies buried as much as 2,000 feet inland as a result of fill projects. And new fill projects are likely in the future.

The industrial park development and proposed expansion of the state port facilities will require additional new land construction in the area between Brookley and McDuffie Island. Such development is not without repercussions. The efficiency of storm sewers that outfall in the fill area may be affected. Flooding problems in some parts of Mobile may be related to existing shoreline development that has altered drainage. The problem of increased pollution is always present as additional modification and development take place. Disposing of dredge spoil, a potential pollutant, is a growing problem. Planners must take into account the total urban system of Mobile before future projects take place. The citizens of the city must be alert to possible problems *before* new filling, dredging, and construction, rather than reacting after the fact.

From the standpoint of coastal hazards to the individual residence or business, flooding is the greatest threat. Frederic, which was a 1-in-25-to-30-year storm, flooded businesses in the vicinity of Water Street in downtown Mobile. Yet the July 1916 flood was 2.8 feet higher than the one in 1979! Four other hurricane-related floods in this century have come within 2 feet of Frederic's flood level. Avoid low-lying areas along the waterfront, Threemile Creek, and the adjacent wetlands that are in the flood zone.

Mobile Bay: western shore

Figure 4.25 characterizes the hazards of the west side of Mobile Bay. Like the eastern shore, storm-surge flooding and shoreline erosion are the 2 common threats to bay-front property. Hurricanes Frederic and Camille generated flood levels ranging from 6 to 14 feet above mean low water along this coast. Many cottages were damaged by Frederic's floodwaters, and associated wave activity destroyed piers, seawalls, and other waterfront structures. Although erosion rates are highly variable, locally as much as 8 feet per year average loss occurs.

As a general rule when choosing a site for low risk, try to locate at an elevation of at least 10 feet. Stay well back from the shoreline, especially if there is evidence of erosion. Such evidence is usually obvious in the form of a cliff or scarp at the back of the beach, fallen trees on the beach, stumps or roots of former trees in place on the beach, or simply that the beach is narrow or absent. Private erosion control measures (for example, bulkheads, and groins) also reflect the problem.

Locally, narrow fringes of marsh mark the shore. Do not regard such marsh as unsightly or something to be removed. The grasses baffle wave energy, trap sediment, and protect the shoreline. Removal of the marsh, even a little patch, may trigger shoreline erosion. Likewise, flotsam of tree trunks and stumps is common in some areas as a result of the shore retreating into forested areas. Such driftwood may be looked on as clutter, but it also may serve as a natural protection against more rapid erosion.

Hurricane-strength winds also should be expected during the lifetime of any given structure along the western shore. Considerable wind damage accompanied Frederic. Appropriate construction precautions may prevent costly damage.

Brookley to Dog River. This area experienced storm-surge levels of 8 to 11 feet during Hurricane Frederic. Development located at lower elevations suffered considerable damage. A significant stretch of Bay Front Drive was flooded, and heavy damage occurred along Highway 163 in the vicinity of Dog River. The Mobile Yacht Club and numerous businesses located on the low, filled marsh at the river's mouth were heavily damaged or destroyed.

North of Dog River Point the present shoreline is in about the same position as it was in the 1850s. Apparently the shore built up until about 1918 and has been eroding slowly since that time. South of Dog River Point to Dog River the history of the shoreline position is somewhat different. After a period of stability in the nineteenth century, considerable erosion has occurred since 1918. The addition of piers, revetments, and similar structures may be contributing to the continuation of this trend.

Hollingers Island. The bay front between Dog River and Deer River is marked by a continuous row of cottages. Most of these buildings were above the 6- to 7-foot flood levels of Frederic and Camille. Structures in the narrow flood zone at or below these elevations were damaged. Sites above 10 feet and back from the shore can be developed with caution. Erosion rates are low along most of this stretch but will vary from site to site. The extensive marsh shore between Deer River Point and Deer River has been eroding at rates between 3 to 10 feet per year. Just north of the mouth of Deer River a road-rail line terminal has been built from dredge spoil out into the bay. The effect of this structure on adjacent shorelines remains to be seen.

Deer River to East Fowl River. This mainland shore rises inland to elevations in excess of 20 feet. Developed sites range from those in the flood zone, such as south of the tidal South Fork Deer River and along the small creeks near Bellefontaine, to lots that remain high and dry, such as those between Bellefontaine and Sunny Cove (fig. 4.25). Flood levels associated with Frederic were higher in this area than to the north, as would be expected. The 10- to 15-foot minimum ground elevation is a good guideline for avoiding flooding. Keep in mind that stilt or pole house construction may still be required to place the first floor above the 100-year flood level. Locally, erosion rates can be high in this zone. Look for shore-front evidence of erosion, and talk to the neighbors to see what they have experienced.

Mon Louis Island. Lying between East Fowl River and Heron Bay Cutoff, the northern portion of the island shore is much like the regions described above. Frederic's floodwaters were nearly 14 feet above mean low water. Homes on high ground escaped water damage (for example, around Faustinas), although wind damage occurred. Homes in low areas, such as north of Mon Louis and at the edges of the bayous, were flooded. Historic erosion rates have varied, and individual sites warrant individual evaluation. Generally speaking, however, shoreline erosion is not a major threat at the present time.

From Point Judith south, the southern portion of the region should be looked upon as a high-risk zone for development. The proximity to the Gulf and open water makes the region highly susceptible to flooding (fig. 4.25). In this case, evacuation routes may be cut off, so if you do live in the area, evacuate early when the hurricane warning comes. Heron Bay, Alabama Port, and

Point Judith were all inundated by Frederic. Locally high erosion rates also are a threat to bay-front property.

Cedar Point. This area and the marsh island between Heron and Mobile bays are good examples of the fragility of coastal environments, physically, biologically, and as escape routes during storms. Over the years erosion is the dominant process to affect this area, especially Cedar Point. The point eroded and migrated northwestward for hundreds of feet over the past century. Modern erosion rates are in excess of 8 feet per year at Cedar Point. This marsh island is the mainland approach route off the Dauphin Island Bridge and causeway. The 1979 hurricane not only destroyed the bridge but washed out segments of the road. Keep in mind that a very small break anywhere along Highways 163 and 188 in this area is sufficient to trap evacuees. The Heron Bay Cutoff bridge and especially the low road north of Cedar Point may be the weak links in the escape chain. *Early* evacuation is a must for residents of southern Mon Louis Island as well as Dauphin Island.

Mississippi Sound: Alabama shore

Mon Louis Island–Portersville Bay. Most of this coast is salt marsh broken by tidal creeks (figs. 4.25 and 4.26). The marshes are not suitable for development, both from the standpoint of coastal hazards and their importance as marine nurseries. Many fish and shellfish spawn in these creeks and wetlands. Every acre of marsh lost to development is a loss to the fishing industry. The marsh seems vast, but each small area dredged or filled, each acre that receives polluted water, adds up to a large cumulative loss for coastal residents.

Storm-surge floods totally inundate these marshes (Frederic: 8 to 9 feet above mean low water) as well as the adjacent inland areas. Marsh shorelines are very unstable and are eroded rapidly. Modern erosion rates for representative localities, such as Barron Point, Cat Island, and Marsh Island, range between 5 to 11 feet per year (reference 58, appendix C).

West of Bayou Como and up Bayou La Batre is an area of old recreational development (San Souci Beach and south of Coden) and the newer commercial development at Bayou La Batre (fig. 4.26). San Souci translates to "without care" or "without worry." Perhaps "Avec Souci Beach" would be a more appropriate name to imply that development in this area should proceed *with care!*

It is difficult to imagine this area as a once popular resort. Today the road is at the edge of Portersville Bay, separated from the water by a deteriorating steel bulkhead. The numerous patches in the road, refill in back of this wall, and repaired sections of the bulkhead are evidence of an erosion problem. The bulkhead is a miniature seawall. The beach is absent. A row of summer cottages and some of the old resort buildings remain, but they face a questionable future. The absence of a protective beach dune system, the low elevation, and potentially high flood levels make a poor combination for safe development. Anyone depending on the coastal road for evacuation should leave very soon after the warning comes!

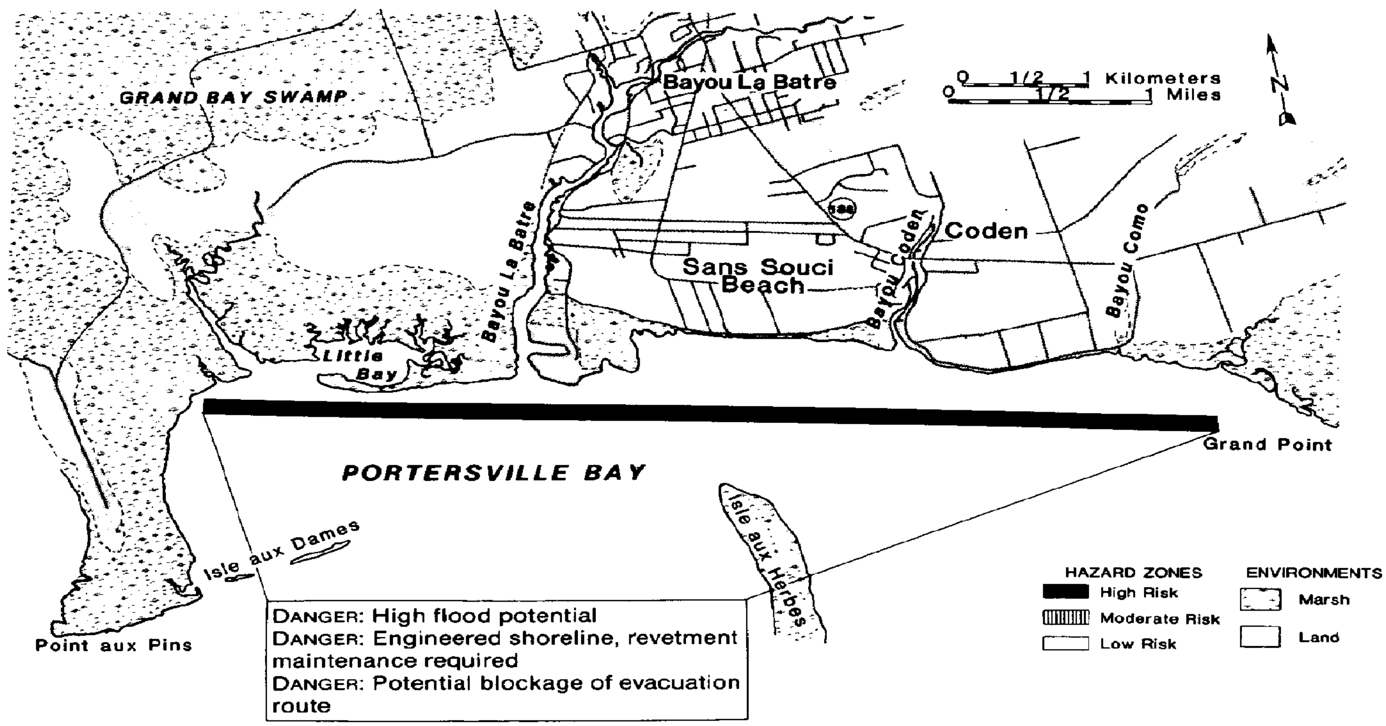


Fig. 4.26. Site analysis: Mississippi Sound (Portersville Bay).

The prospective buyer/builder also should be cautious of areas along or near the bayous. Even though inland from Mississippi Sound, hurricanes push floodwaters to the heads of bayous. Sites above 10 feet in elevation are safer from flooding than lower elevations, but elevated structures may be required to make sure the living unit is above the 100-year flood level. High elevation alone is not sufficient for establishing site safety. For example, west of Bayou La Batre is the Grand Bay Swamp. Much of the swamp is at or near the elevation of 10 feet. The forest vegetation and the elevation may give a false impression of stability, but a coastal swamp is not a safe place to build. It is subject to significant flooding during storms. The same is true for the marshes around Little Bay and the western shore of Portersville Bay. Two to 3 miles inland, though, is the edge of the upland, rising from 30 feet to elevations greater than 90 feet. The upland provides safe sites with close proximity to boat launches, bay access, and recreational sites.

Grand Bay. From Point Aux Pines to the Grand Batture Islands the shore is a continuous expanse of salt marsh, extending inland into swamps, and not illustrated in the map series. As noted above, this marsh also is subject to flooding and is highly erosion-prone (3 to 9 feet per year). Because it is unsuitable for development, and because of its great economic importance to the state of Alabama's fishing industry, this entire area should be preserved in its natural state.

Fig. 4.27. Active dune field, eastern Dauphin Island. Dunes have migrated into edge of forest. The area forested in the middle of the island behind this continuous dune ridge was the only area of Dauphin Island not flooded by Hurricane Frederic's storm surge. Photo by Bill Neal.

Dauphin Island

Prior to the War Between the States, Petit Bois Island was in Alabama. Over the last century, however, Petit Bois Pass migrated laterally to the west, as did Petit Bois Island (fig. 2.3). Today Petit Bois lies entirely in Mississippi, giving Dauphin Island the distinction of being Alabama's only barrier island. This 15-mile rampart of sand protects Mississippi Sound and the mainland shore from the direct onslaught of hurricanes, but like Petit Bois it is an ephemeral feature. Hurricane Frederic in 1979 was the most recent in a series of storms to rake the island. The eye of the hurricane passed over the center of the island, and the storm's economic fallout brought Dauphin Island to the center of a political storm over barrier island policies.

Dauphin Island is not a typical barrier island after the fashion of the Texas or Carolinas' barriers. The island did not form far from its present position and migrate across the shelf as sea level rose. The eastern 3.5 miles of the island was once a hill on the coastal plain mainland that existed in this position when sea level was lower. As sea level rose, flooding the former mainland, only the upper part of the hill was left emergent. Wave and wind erosion and longshore drift began to rework and redistribute the sand making up the hill. Gulf-side beaches formed, and a dune field developed at the back of the beach. These dunes are still active, migrating slowly into the forest that has grown on the former upland (fig. 4.27).

Sand carried to the west began constructing a spit, extending the island from the former hill to its present tip some 11 miles to the west. The character of the spit is more typical of an active barrier island, and it is classified as a high-risk zone (fig. 4.28). It is low in elevation (less than 10 feet), narrow in width (less than 1,800 feet), lacks well-developed continuous dunes, lacks good vegetation cover, and is fringed along its bay side by salt marsh. All of the common barrier island hazards apply to this segment of the island, that is, overwash, flooding, wave attack, shoreline erosion, and inlet formation. Said simply, this area is one of the most dangerous on the Alabama coast!

Hurricane Frederic demonstrated the fragility of the spit portion of the island. The storm-surge flood is known to have exceeded 13 feet above mean low water in the Bienville Beach area. How deep it was over the spit area is unknown because the flood totally inundated the natural features against which water levels might be measured! Overwash was extensive and crossed the island into the sound. North-south streets and driveways funneled the overwash across the island. Cottages along Bienville Boulevard were heavily damaged or destroyed. The eye of the storm passed over Dauphin Island so the impact was not as great as farther east, for example, the Fort Morgan Peninsula, West Beach, and Gulf Shores. Imagine waves in Mississippi Sound that could lift and wash away the concrete decking of the causeway and bridge! Developments along finger canals on the back side of the island (Silver Cay and Oro Point) also suffered. Some intercanal property was left as miniature islands, while other canals trapped sediment washed across the island (fig. 4.5). Homeowners were faced not only with cottage repair/reconstruction but also with rebuilding the canals. Silver Cay property owners were faced with a collective out-of-pocket bill in excess of $80,000 for canal dredging and bulkhead repair or replacement. Such potential additional costs are worth considering in site selection next to finger canals.

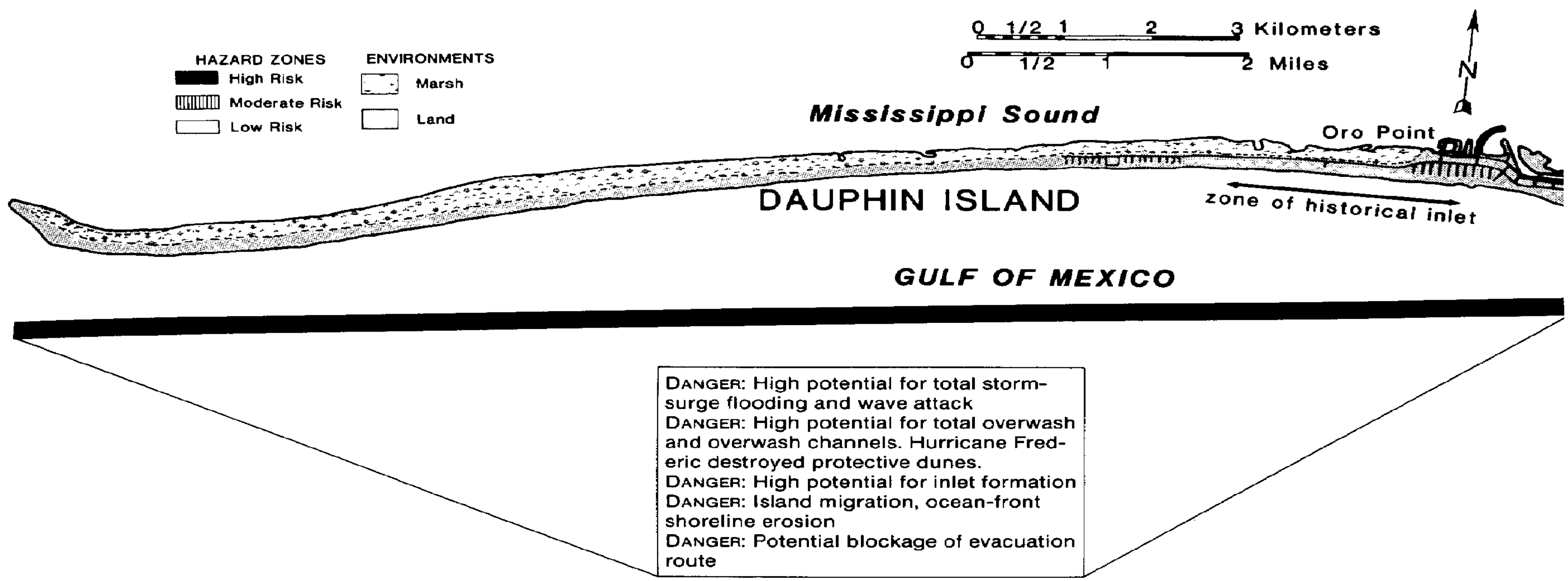
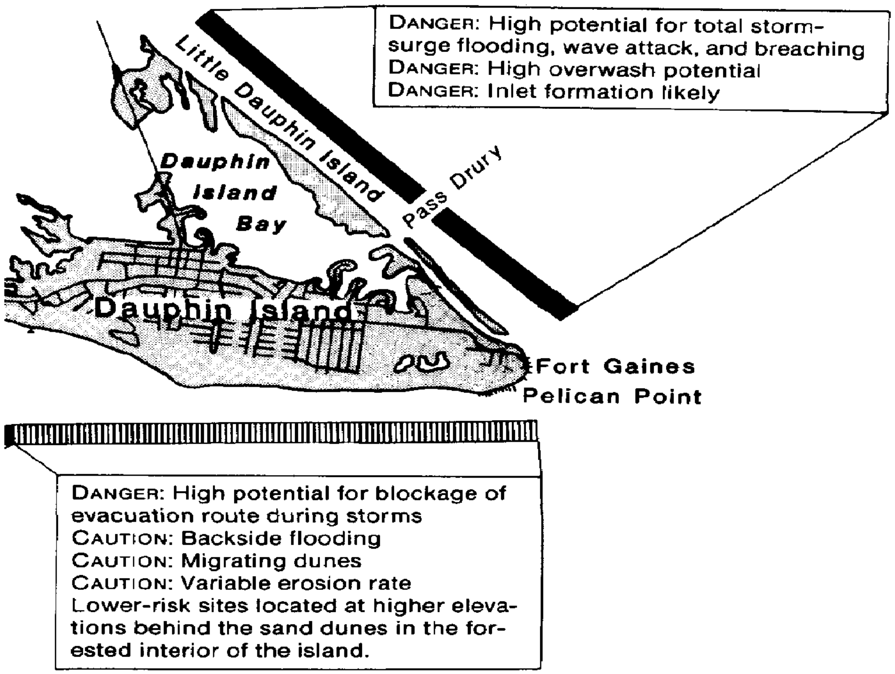


Fig. 4.28. Site analysis: Dauphin Island.



It seems incredible, but after the destruction of Frederic, property owners rushed to rebuild on sites of destruction, made even more dangerous by the removal of protective dunes, stabilizing vegetation, and reduction of elevation (fig. 4.29). Shoreline erosion and the potential for inlet formation add to the risk.

Early in this century a hurricane breached Dauphin Island, forming a 5-mile-wide, shallow inlet. The inlet gradually filled in until a single island had re-formed by 1942. The September 4, 1948, hurricane again breached the island about 4,000 feet west of Oro Point. Extensive overwash occurred at that time as well. The post-1950s development on the spit portion of the island has been in these unstable areas. All sites on the entire spit must be regarded as in the high-risk zone (fig. 4.28). Even the very best construction will be vulnerable in such an area.

Because the spit is rapidly building up at its western end, averaging more than 150 feet per year, it is tempting to conclude that island growth will increase its suitability for development. This is not the case. The western part of the island cannot be developed safely. The entire western segment is migrating northward. As much as 800 feet of northward movement in the last 130 years has been documented. The present Gulf shoreline is now in the former position of the island's Mississippi Sound shore! Put in somewhat different terms, the western end of the island eroded at a rate of over 10 feet per year in a study period between 1917 and 1974. Hardly a wise place to build.

In contrast, the main body of the eastern portion of the island has some stable features, and lower-risk building sites are to be

Fig. 4.29. Development on western Dauphin Island in high-hazard zone. This 1981 photo shows new cottages constructed seaward of the ruins of cottages destroyed by Hurricane Frederic in 1979. The narrow strip of sand in the sound toward the back of the scene is the edge of the storm's overwash. Note low elevations, absence of protective dunes, extremely close positioning of cottages next to the beach, and narrow width of island. During major storms the driveways will become natural conduits for overwash sand, blocking the only escape route. Photo by Bill Neal.

found in the interior forested area behind the high frontal dune ridge. Island width extends to 1.5 miles, and the former upland is heavily forested with oaks and pines. With the exception of the extreme eastern end of the island, near Fort Gaines, there is an extensive and well-developed dune system between the Gulf and the forest. These dunes rise to more than 40 feet above sea level, and the dune line provides a protective barrier to the property along the north-south streets (for example, Audubon Street, Johnston Drive, Hernando Street, and Iberville Drive) (figs. 4.27 and 4.28). The best island development sites are in this area at the higher elevations. The dunes, however, also present a hazard. For example, in the vicinity of the Dauphin Island school the large dunes are migrating north. Vegetation has been planted and fences constructed in an attempt to stabilize the dunes; however, if these efforts fail the dunes will continue to invade the forest. A house built too close to the active dunes may become an unplanned underground house! South of the dunes, tree trunks are appearing as the dunes move, indicating that the dune line has migrated for a distance at least equal to its width.

The undeveloped eastern end of the island includes the 159-acre National Audubon Wildlife Sanctuary, a remnant of the former natural character of the island. The land is owned by the county and leased to the National Audubon Society. The preserve is an important habitat for numerous terrestrial and semiaquatic species, as well as a resting area for migrating birds; it also provides a resource for enjoyment by island residents and visitors that is missing on most developed barrier islands.

Hazard zones to be avoided in the eastern section include the ocean-front area between the beach and the high dune line. This area is subject to storm floods and wave attack, overwash, and occasional erosion. It is undeveloped and should remain so. The eastern end of the island includes Fort Gaines and the Marine Environmental Science Consortium facility. The shoreline along Pelican Point to the front of the island has been stabilized by groins. The groins on the front side have become detached during storms, allowing some sediment bypassing (fig. 3.4). After Hurricane Frederic, considerable amounts of sand were pumped up on the eastern end of the island, burying some of the groins. The sand provided a temporary beach, but erosion is removing the sand, reexposing the groins. Additional projects will be necessary in the future to maintain the shoreline position.

The sound side of the eastern portion of the island is extensively developed, including finger canals and land areas built up from dredge spoil. All of the back side of the island was flooded by Frederic and will be flooded in future storms. Development along the bridge approach received considerable damage.

Little Dauphin Island. A narrow ridge of sand and back marsh forms the barrier enclosing Dauphin Island Bay. At one time it was connected to the main island and probably derived part of its sand supply from the eroding east end. The connection was severed with the dredging of Government Cut, a water access route between the adjacent bays. The cut is not unlike the various inlets that have breached the island in several places over the years. The island is very low and unstable. One would conclude that this bit of moving sand is unsuitable for development, but the original plans for the new bridge are said to have included an exit ramp onto Little Dauphin Island. If so, the ramp plan was abandoned, and the area was recently included as a unit in the Bon Secour National Wildlife Refuge.

How do such high-risk zones as those on Dauphin Island come to be developed? Access is the answer. The development of Dauphin Island is largely the result of the ease of access provided by the Dauphin Island Parkway Bridge (Highway 163), completed in 1954. Development, once in place, created the political pressure to maintain access that allows for more development. Frederic's destruction of the bridge was met with nearly immediate Federal Highway Administration approval of an "emergency" grant to rebuild the bridge. The $38 million is a subsidy that serves redevelopment in high- to moderate-risk areas that had only 1,600 permanent residents at the time (references 93–95, appendix C). One study calculated that the bridge subsidy amounted to $50,000 per structure on the island before the storm, or $20,000 per structure if all mapped lots were developed! These monies are on top of the payoff in federal flood insurance, low-interest loans from the Small Business Administration, federal dollars for a new sewage treatment facility, federal dollars to underwrite the emergency activities of the Army Corps of Engineers, and other expenditures of federal and state tax revenues. It adds up to a financial boon to refurbish an island that could be wiped out again next year, or in 10 years, or several times in the next century.

Hurricane Frederic's impact on Dauphin Island focused the nation's attention on the folly of barrier island development at the expense of the general public. As a result, it became the center of controversy over American barrier island policy and was important in the framing and passage of the Coastal Barrier Resources Act. When the next storm redestroys the federal investment, Dauphin Island may become the straw that broke the camel's back, and the next round of legislation will be aimed at developed barrier islands.

Sand Island and Pelican Island. These islands lie south of the eastern end of Dauphin Island. The position and size of these sand bodies change dramatically with time. They build up from sand shoals to maximum size during times when no hurricanes come into the area, and then they virtually vanish during hurricanes. Such islands are unsuitable for development. The lighthouse at the entrance to Mobile Bay was built on such a feature (fig. 1.2). The island migrated away leaving the lighthouse standing in the water!

Mississippi

Jackson County

With the exception of Pascagoula, Mississippi's eastern shore is lightly developed. Extensive areas of marshland and limited access account for the slow development, but inland growth is toward the shore. Developers are discovering the area south of Gautier, the sandy ridge of Belle Fontaine Point, and the shores of Davis Bayou. Property along smaller bays and bayous provides water access. Such new developments are not always in low-risk areas. The county is divided into 4 segments for purposes of discussing hazard evaluation, namely, the area east of Pascagoula, Pascagoula and vicinity, the region between Pascagoula Bay and Davis Bayou, and Ocean Springs.

Grand Batture Islands, Point Aux Chenes, Bayou Casotte

A vast marsh swamp straddles the Alabama-Mississippi state line. The north shore of Mississippi Sound from Bayou La Batre to Point Aux Chenes is a complex of embayments, bayous, and tidal creeks separating marsh tracts that grade inland into swamp. The Grand Batture Islands are the thin sandy edge of this watery land, all that remains of a once-extensive island chain. The islands are barely sandy enough to call beach, and many are flooded marsh remnant rather than barrier islands. As these protective islands disappear, the marsh boundaries of the old, abandoned Escatawpa Delta come under wave attack and rapidly erode. These extensive fragile marshes and islands probably never will be considered for development, and rightly so, for they lie in a high-hazard area (not shown in the map sequence).

Inland, however, the swamp is characterized by bottomland forest that gives an impression of stability. It is not inconceivable that building sites could be developed, especially if fill were added to build up the elevation. But appearances can be misleading because the area is unsuitable for development. The low elevation, unstable subsoil, groundwater problems, and frequency of flooding create a situation that should keep this land in its natural state, or allow only forestry or restricted agricultural uses. For instance, the area was extensively flooded 3 times in the 15-year period from 1965 through 1979. The flooding extended as far inland up the valley of the Escatawpa River as U.S. Highway 90.

An extensive area of lowland in the flood zone south of the Jackson County Airport has been reclaimed and built up with fill to develop the Bayou Casotte Industrial Area. The development provides a port facility.

Low-risk residential development areas all lie inland at elevations of at least 10 feet above sea level. You should consult flood maps when choosing a site (see appendix B and references 61 and 62, appendix C), but general areas above the flood zone include the land north of the Jackson County Airport, Kreole and Moss Point away from the wetlands and floodplain of the Escatawpa River, and between Kreole and Orange Lake north of U.S. 90.

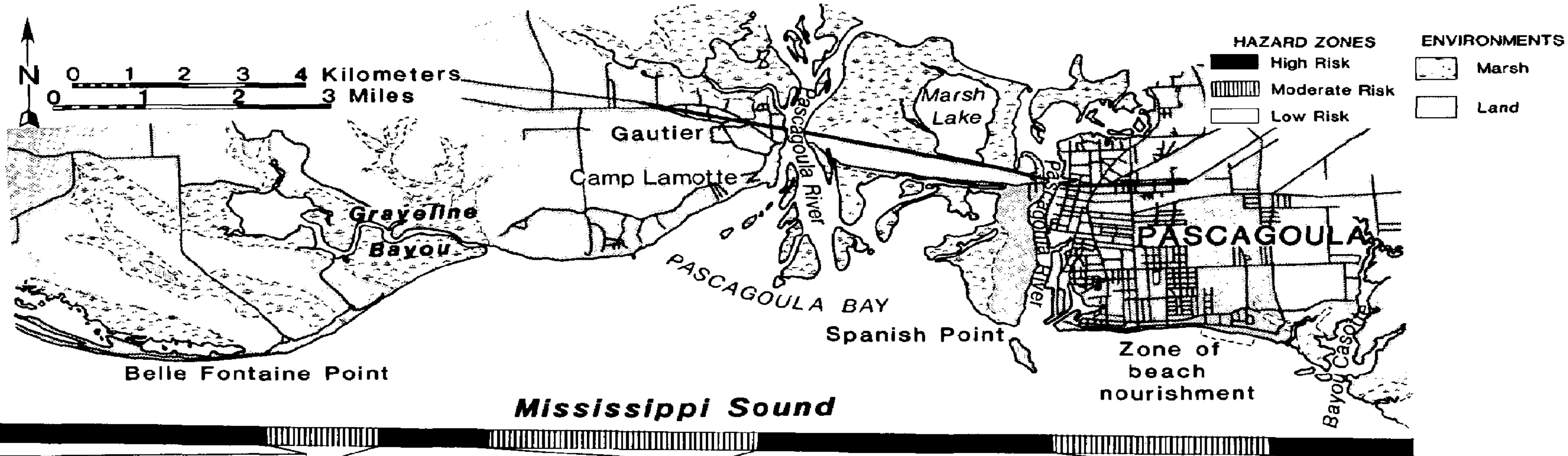
Only the westernmost part of this area is shown on the risk maps (fig. 4.30). Development along Back Bayou and Bayou Casotte to east Pascagoula is in a high-risk zone. Some damage was sustained in this area during Hurricane Frederic, and Hurricane Camille caused severe flooding.

Pascagoula-Pascagoula Bay

The shoreline of Pascagoula (fig. 4.30) exemplifies the urban, engineered shoreline. No remnant of a natural beach remains along the 2.2 miles of Mississippi Sound shore, and the riverfront is highly modified. The small public beach is artificial: pumped sand in front of the seawall, held in place by a second wall. Along most of the waterfront only a concrete seawall separates the waves from the land. Waves break along the wall, sending spray onto Beach Boulevard, the buffer zone between sea and property fronts. West of Market Street the elevation rises abruptly so that the land as little as 1 block inland is above the flood zone. Such inland property falls into the low-risk category, providing access to both the amenities of the coast and an urban environment. Going to the east, however, the nearshore elevations are lower. Flooding is a likely hazard, and caution is in order.

The narrow buffer zone withstood Hurricane Betsy's 5.5- to 6.4-feet above sea level flooding in 1965 and Hurricane Frederic's 5.8-feet storm surge in 1979. The 9 inches of torrential rainfall that accompanied the latter storm did cause some inland flooding, and high winds caused considerable damage to homes and businesses. Both storms flooded parts of Beach Boulevard, but it was the low floodplain of the Pascagoula River that was most extensively flooded.

Hurricanes Betsy and Frederic were storms with a recurrence interval of 1 in 25 to 30 years, although they came just 14 years apart. Pascagoula withstood these storms fairly well, but it was not in the highest impact zone east of the eye. In 1969 the city and outlying areas were extensively flooded by the storm surge associated with Hurricane Camille. Floodwaters rose to more than 11 feet above mean sea level, and flooding was extensive for several blocks inland along the riverfront and in the southeast part of town. Again, Pascagoula was far enough from the eye of the storm



DANGER: High flood potential; some cottages in velocity zone
DANGER: Overwash potential
CAUTION: Potential for inlet formation
CAUTION: Severe local shoreline erosion
CAUTION: Low evacuation route

DANGER: Flood zone
CAUTION: Overwash potential
CAUTION: Shoreline erosion
CAUTION: Low evacuation route

DANGER: Flood zone
DANGER: Overwash potential
DANGER: Inlet migration
CAUTION: Erosion
CAUTION: Low evacuation route

DANGER: Shore-front flood zone
CAUTION: Local shoreline erosion
Good sites above 10′ elevations and away from shoreline. Shoreline owners should preserve protective marsh fringe.

DANGER: High flood potential from both the river and storm surge
DANGER: Shifting channels
DANGER: Shoreline erosion; unstable marsh

DANGER: Flood zone
CAUTION: Engineered-urbanized shoreline; seawall and/or beach maintenance required to protect property
Good inland sites at elevations above flood zone

DANGER: High flood potential
DANGER: Avoid low elevations, marsh, and shorefront
CAUTION: Local shoreline erosion

Fig. 4.30. Site analysis: Bayou Casotte–Pascagoula to Belle Fontaine Point.

to escape the devastation that ravaged the area from Bay St. Louis to Biloxi.

In each case, Petit Bois and Horn islands, barrier islands 5 to 10 miles south of the city, softened the blow and reduced storm surge. Round Island, between Pascagoula and Horn Island, also has been a buffer to absorb wave energy, but it is eroding away. Its landmark lighthouse will soon be claimed by the sea. The barrier islands are part of the Pascagoula shoreline's "luck," but that luck will not last forever.

Future development in the greater Pascagoula area should be on sites at least 10 feet in elevation. Construction should take into account the high probability of hurricane-strength winds, and proper precautions should be observed. The same is true for Moss Point and vicinity.

Gautier to Ocean Springs

Gautier to Graveline Bayou. This shoreline is the west side of Pascagoula Bay. The land slopes rapidly from sea level to elevations of more than 10 feet. Camille's flood level was 12.7 feet here, but good waterfront sites exist at elevations above the 1-in-50-year flood level. Locally shoreline erosion may be a problem, but a check for stumps on the beach or other evidence of such erosion will allow you to avoid such areas. Locations back from the water's edge in well-vegetated areas are usually the best. This also is true along bayous. If fringing marsh is growing along the shore, preserve it as insurance against erosion. Remember to take precautions against potential wind damage. Developments include Camp Lamotte and Seacliffe. Be wary of sites on finger canals. Figure 4.30 classifies the area as being a moderate-risk zone for waterfront sites, low risk for inland sites.

Belle Fontaine Point. The area here lies between the mouth of Graveline Bayou to the east (fig. 4.30) and Davis Bayou to the west (fig. 4.31). The marshes are obviously unsuited for development, but the adjacent land is not much better, even though development is taking place. Between Graveline Bayou and Belle Fontaine Point the shoreline is undergoing erosion. The beach immediately in front of the golf course near the water tower shows typical evidence of erosion (stumps, scarping, and past road damage). Any structure built close to the shore will be "on the water" in a few years! Storm flooding also is a threat.

West of the point, development is occupying the narrow, lengthening sand spit. Longshore currents are eroding the eastern segment and transporting the sand to the western segment, causing it to grow toward the mouth of Biloxi Bay. The spit is so narrow, of such a low elevation, and usually lacking good protective sand dunes that the future of most cottages built there is easily predicted: destruction by a future hurricane just as the previous cottages were destroyed by Hurricane Camille. The spit is highly susceptible to flooding, wave erosion, overwash, and potential inlet formation. Late evacuation will be impossible. Surviving structures may be on an island or standing in the water of a breach!

If you are willing to take a high risk, seek the more stable sites. Here and there are good dunes and thickets with live oaks. Set back from the waterfront. If buying an existing cottage, check

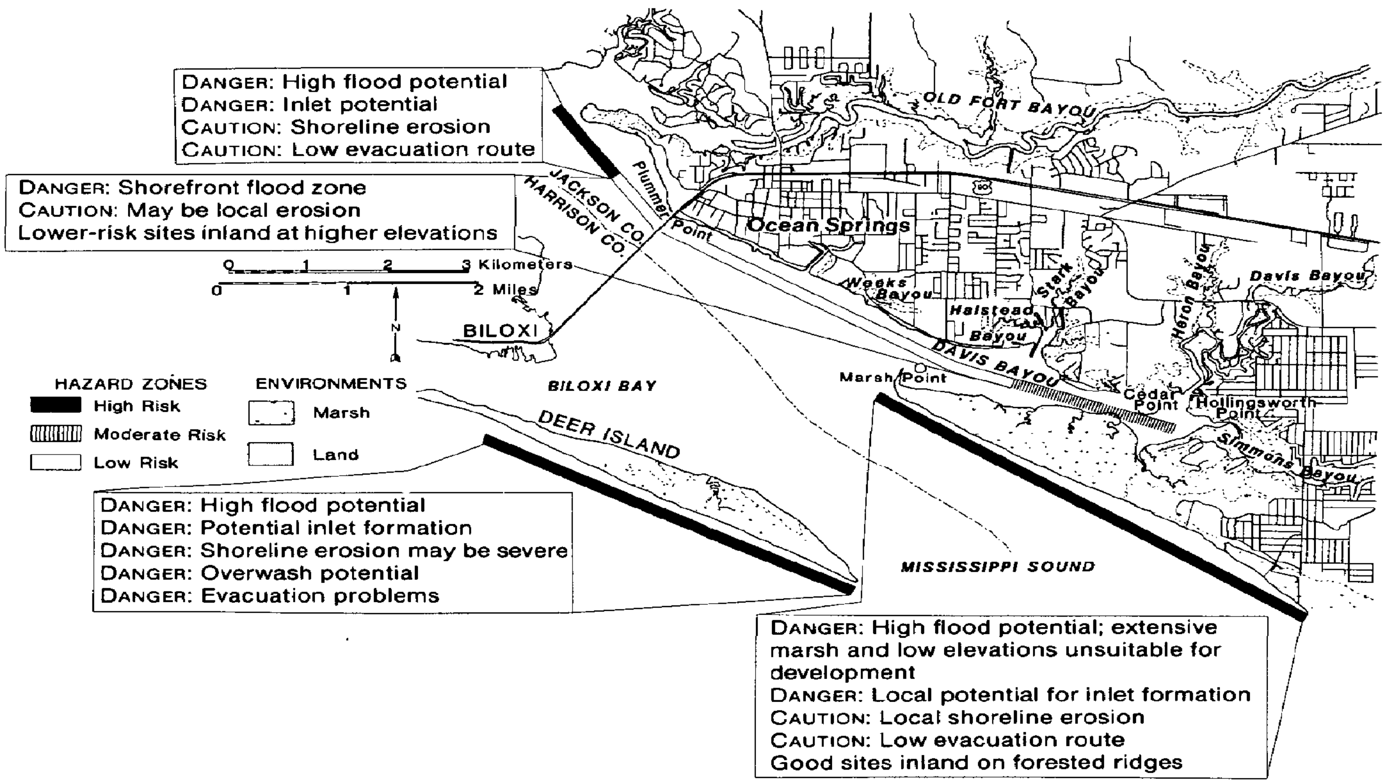


Fig. 4.31. Site analysis: Belle Fontaine Point to Ocean Springs, and Deer Island.

construction quality carefully. When the storm warning comes, evacuate early.

Better yet, sacrifice being right on the water for a much lower-risk inland site, such as along Point Aux Chenes Road where elevations are above 20 feet. Your heirs instead of the sea will inherit your cottage.

Marsh Point. This area marks the western extension of land beyond Belle Fontaine Point (fig. 4.31). Most of the sound shore is marsh, but a long upland lies between Simmons Bayou and Mississippi Sound. Although the upland is not waterfront property, the elevations of 20 feet (Camille flooded to 14 feet) and vegetative cover may make it suitable for future development. Public boat access could be made available without disturbing significant areas of marsh.

Davis Bayou. Davis Bayou's north shores and bayou accesses provide upland development sites on or near the waterfront. Hurricanes push floodwaters to the heads of the bayous and generate destructive winds even for upland sites. Nevertheless, the area east of Ocean Springs has many developed and developable sites in the low-risk category (fig. 4.31). Camille's flood level reached nearly 16 feet, but site elevations of 12 feet should be above most floods. If storm evacuation is necessary, avoid the waterfront roads as escape routes.

Ocean Springs

Ocean Springs lies at the head of Biloxi Bay and east of the Back Bay of Biloxi. Although peninsular in character, most of the city is at an elevation above the storm-surge flood zone. Hurricane Camille, an extreme, pushed water levels to 15.8 feet above mean sea level, flooding parts of the town. The presence of Deer Island and Marsh Point afford protection from the open waters of Mississippi Sound (fig. 4.31). As in all of the area, low-lying coastal land is subject to frequent flooding. The beach fronting Ocean Springs is artificial and will not survive severe storm wave attack.

Keep in mind that high rainfall is associated with most hurricanes, so even at higher elevations you should choose a site with good drainage. Wind and wind-blown debris also should be taken into account. All of these comments also apply to the area along Old Fort Bayou.

Gulf Islands National Seashore

Petit Bois Island and Horn Island in Jackson County and Ship Island in Harrison County make up the Gulf Islands National Seashore (along with part of the Florida barrier system; see appendix B, Parks and recreation). Cat Island, the westernmost island of the chain in Harrison County, is not part of the designated federal seashore (fig. 1.1).

The islands, 7 to 15 miles off the mainland coast, form a fragile division between Mississippi Sound and the Gulf of Mexico. These long, narrow strips of sand are migrating as a result of marine processes (see chapter 2).

Exposure to the open Gulf makes the islands vulnerable to high wave energy and storm surge so that the fronts of the islands commonly erode. The sand either is transported to the west by longshore drift or across the islands as overwash during hurricanes. The eastern ends of the islands lack a nourishing sand supply and erode significantly, while the western ends lengthen as sand is added from the longshore drift. The net effect is that the islands, and the passes between them, are migrating to the west and slightly landward.

Fortunately, the islands' national seashore designation removes them from the realm of development. All are high-risk areas in terms of exposure to natural hazards and not suitable for development. Their cost to taxpayers as parks and natural areas will be much less than the subsidies that would be required to develop and repair them if they were commercially exploited. In their present state the islands generate tourism revenues and preserve wildlife habitats, including those important to the state's fisheries.

Petit Bois Island

Thirty-five to 40 years ago the eastern end of Petit Bois Island was in Alabama. If it had been covered with cottages at that time, they would have fallen into the sea long ago. Petit Bois is a typical barrier island: long, narrow, and migrating. The low, discontinuous ridge of dunes through the middle of the island is only slightly more than 10 feet above sea level at its highest points. Hurricanes flood the island, carrying sand across to the sound as overwash. Dr. Ervin Otvos of the Gulf Coast Research Laboratory has documented that both the front and back sides of the island are eroding. Marsh peats, which formed in marshes on the back side of the island, are now exposed on the eroding beaches. Dr. Steve Shabica, a research oceanographer, has reported that the island is now one-half its original size.

The ends of the island are changing in response to both nature and man. The eastern end is eroded by the westward drift and the migration of Petit Bois Pass. Normally, the western end would be an area of shoreline growth, but dredging of the shipping channel for Pascagoula through Horn Island Pass is removing sand and destroying shoals that act as protective buffers against beach erosion. Although the island may not totally disappear, this shrinking results in loss of wildlife habitat and the loss of the mainland shore's protection against the full force of hurricanes. People living on the Jackson County coast should be concerned about the future of Petit Bois and Horn islands.

Given the rapid disappearance of the island, its historic lateral shift, and the extremely high-risk nature of the island with respect to natural hazards, it seems inconceivable that it would be considered for development. Incredibly, at the time the Gulf Islands National Seashore was taking shape, private land on Petit Bois was being traded with the intent to develop the island! This land ultimately was condemned under the eminent domain procedure and is now part of the Gulf Islands National Seashore.

Horn Island

De Bienville is said to have named this island in 1699 when one of his men lost a powder horn there. From that time on, human beings occasionally occupied the island but never dominated it.

Commercially hunted, marginally farmed, used for recreation of various sorts from the earliest days, used as a gunnery range and home for a biological warfare experiment station during World War II, all suggest a search for some ideal use. Designation of a portion of the island as a national wildlife refuge in 1958 was a return to what the island was designed for—home to hundreds of species of aquatic and land plants and animals.

At more than 12 miles in length, and with dunes a few tens of feet in elevation, Horn Island is the largest of the barrier chain. In spite of its size, it is, like Petit Bois and Ship islands, an unstable feature. Shoreline erosion, island migration, and overwash are all at work. Hurricane Ethel (1960) took away a half-mile of the island's eastern end, while the western end grew by a quarter-mile. In 1906 a hurricane swept away the island's lighthouse, its keeper, and his family. But these events pale when compared with the impact of Hurricane Camille. Waves ate away at the beach, leveled dunes, and flooded across the island, sweeping debris all the way to the mainland coast. The island lost 1.6 miles off its western end and one-third mile off its eastern end in the 1969 storm.

Isle of Caprice (Dog Island). Mentioned in chapter 1, this island was part of the dynamic sand shoal off the western end of Horn Island in Dog Keys Pass. Generalizations can be dangerous, and the model of western migration does not mean that the barrier islands always show growth on their western ends. Hurricanes have proven the opposite, and so has shoreline erosion.

Where Dog Island stood with a dance pavillion, restaurant, casino, pier and docks, small cabanas, trees, scrubs, and sea oats in the 1920s and 1930s, today there is only ocean. Fire destroyed some of the buildings; nature took the island.

Horn Island and its associated shoals are a natural laboratory where change can be studied. Perhaps it will give up secrets of barrier islands that have been lost in the commercial scenery-of-sameness of much of America's coast.

Ship Island

The western island of the Gulf Islands National Seashore lies in Harrison County. Ship Island, whose name reflects its long history as an anchorage, is the most accessible of the national seashore barriers (see appendix B, Parks and recreation). Fort Massachusetts and the island's role in the Civil War, as well as its natural state as a barrier island, make this an excellent island to visit.

In character the island is much like Petit Bois. Hurricane Camille breached the island producing Ship Island Channel, creating what are now commonly referred to as Big Ship and Little Ship islands. If no significant storms occur, the breach may close naturally. The only certainty is change. Rubble from an 1854 brick lighthouse that was felled by the retreating shoreline in the nineteenth century attests to a history of change.

Harrison County

In addition to Ship Island, Deer Island and the mainland shore of Mississippi Sound compose the Harrison County coast. The mainland shore consists of approximately 27 miles of continuous urban-suburban development. The area's economy is tied to a complex of tourism, commercial fishing, harbor facilities, light industry, military installations, and related businesses, all in the vulnerable coastal zone.

In 1915 one of the most costly Gulf Coast hurricanes inflicted heavy damage to this area. More than half of U.S. 90 was washed out between Biloxi and Pass Christian, along with a great deal of beach-front property. The response between 1925 and 1927 was to build 25 miles of seawalls from the Biloxi lighthouse and Henderson Point. With the exception of 1 mile of concave wall, the seawall is the concrete step type, ranging in height from 8 to 11 feet.

Construction of the seawall was a commitment to hold a fixed shoreline and led down the road of shoreline engineering. Five sections of wall failed in the 1947 storm as all of the seawall was topped, and property damage was again extensive. As a result of this storm, Biloxi adopted the Southern Standard Building Code, and the 1948 River and Harbor Act authorized the construction of an artificial beach to protect the wall and beachless shoreline. In 1951 a 300-foot-wide, 5-foot-high beach was placed in front of the wall. By 1965 its width had been reduced to between 140 feet and 250 feet. Conditions during Camille were such that the beach was not severely damaged, but clearly a long-term and costly commitment has been made to this engineered shoreline.

Natural processes such as erosion-buildup, overwash, dune formation, and migration have lost their significance in coastal evolution. Army Corps dredges and county dump trucks have become part of an artificial equilibrium. Camille brought home the hard lesson that such a system is not a defense against property loss. The seawall "held the line" of the coast; it did not save the beach or even the property in back of the wall. The system has served its purpose in lesser storms, but the "big event" obviously cannot be dismissed. Social questions such as the scenarios outlined in chapter 3 will become the new determining factors in the future of this coast. Fortunately, the protective offshore barrier islands will remain in their near natural state as part of the Gulf Islands National Seashore. Only Deer Island, the low, narrow island extending southeast from Biloxi, is threatened with high-risk development.

Figures 4.32 through 4.36 classify the risk categories of the Harrison County coast.

Deer Island: a case example of development controversy

The "Friday the 13th" arrival of Pierre LeMoyne Sieur d'Iberville on the *Ile-aux-Chevreuiles* in 1699 may have been an omen. Just as the island beckoned this early explorer, it has beckoned other coastal adventurers. Today, as a remaining stretch of open coast, it beckons the developer. History does repeat itself.

In 1915 Deer Island was being advertised as the "Coney Island of the South" with a pier, dance hall, merry-go-round, penny arcades, refreshment stands, and the opportunity to buy into this paradise—a lot complete with bungalow. The hurricane of 1915 destroyed the amusement park in its first season, killed real estate sales, and led the financiers to prudently withdraw.

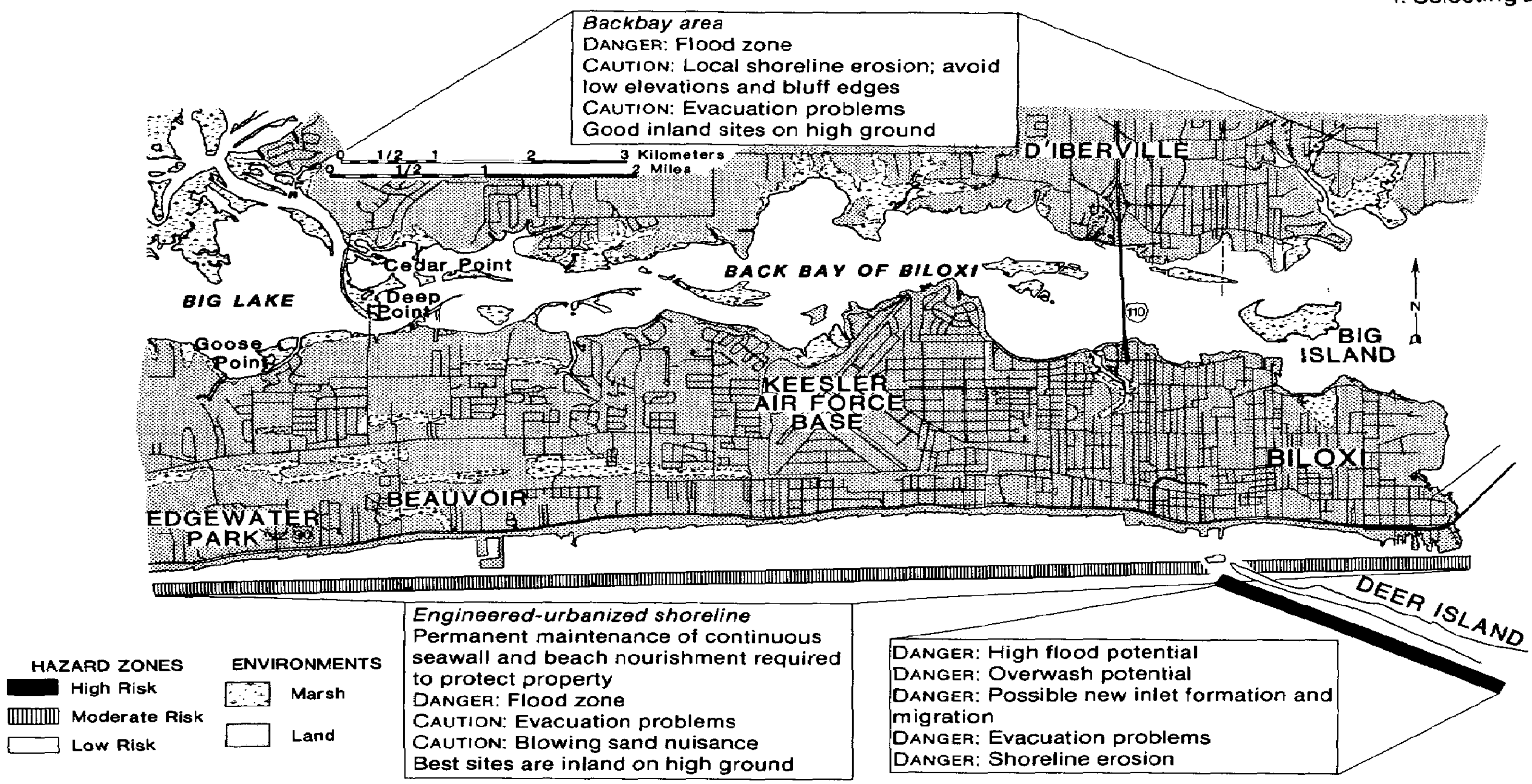


Fig. 4.32. Site analysis: Deer Island–Biloxi–Edgewater Park–Back Bay of Biloxi.

The decision was a wise one because by all criteria Deer Island is a very high-hazard zone for development (figs. 4.31 and 4.32). Although this island lies behind the barrier island line of the outer Mississippi Sound, it behaves as a true barrier island. Stumps on the beaches attest to its migrating character, and its low elevation allows overwash and storm-surge flooding. The lack of a continuous natural sand supply accounts for retreating beaches. The narrow width leaves the island vulnerable to inlet breaching. The impact of frequent storms accounts in part for the island's remaining in its natural state. However, as the northwest end of the island has built up, the distance between island and mainland is ever shortening. Today only the distance of a football field separates the two, half the distance of open water that existed in the 1850s.

By the late 1970s the island was coming into the center of a new storm. This storm was not nature's as in the 1915 destruction, or Camille's submergence and battering, or the dozens of other storms that have raked the island. The modern storm is the political-economic-social controversy generated by a new set of proposals to develop the privately owned island; it is a case example to the student of coastal development.

Generator of the controversy is the "promise-them-anything" developer. In this case the following claims were made: (1) concrete condominiums designed to withstand 250-mph winds, as tested by a major university (the university had not tested, was unaware of any other such tests, and had given no stamp of approval to the design); (2) the beaches to be nourished (the same developers bulldozed several acres of dune beach complex in Florida after agreeing with the local county commission not to develop such areas; such sand as needed on Deer Island is in limited supply and wetland destruction would likely result); (3) mosquito control to be achieved through the use of pesticides (mosquito breeding grounds probably lie beyond limited spraying reach; wetlands would be adversely affected by pesticides); (4) public recreation to be restricted (read this as doublespeak for denied access); (5) vehicular traffic to be limited (and so would the opportunity for swift egress in the event of storm evacuation).

Supporting the developer are local officials (Biloxi's city fathers) who see such development as "excellent" and "a good economic boost." The president of the chamber of commerce envisages an expanding population base as good for business and thinks the proposed development ecologically sound (?), but reserves the right for a change of mind if things don't go as expected (what a "change of mind" will achieve after the damage is done goes unexplained)! History forgotten.

The opposing camp is that of the "environmentalists," which includes views ranging from "leave-it-just-as-it-is" preservationism to those who favor limited development, encouraging recreational and educational uses of this unique asset. That the island is the only place in Mississippi where salt flats and salt pans still exist, that half of the island is salt marsh (fisheries' nursery land), and that it is home to some rare birds and alligators are facts that suggest the total island system is an "endangered species," worthy of limited use.

Perhaps the most important group—the taxpaying public, citizens of the city, county, and state—have little voice in the important controversy. They must rely on the prudence of their elected officials and the coastal governing/regulating agencies. In this case permits were denied by the Bureau of Marine Resources, although some construction did take place.

If Deer Island is developed, there will be winners and losers. The winners will be the developers, contractors, and service units. Short-term winners will be the island dwellers and the local tax coffers—until the first storm. The losers will be the buyers who ultimately lose all or part of their property and possibly their lives, the public denied access to the beach, the wildlife that lose their habitat, and ultimately the taxpayers of the state who will be asked to subsidize infrastructure costs and post-storm cleanup.

Biloxi to Pass Christian

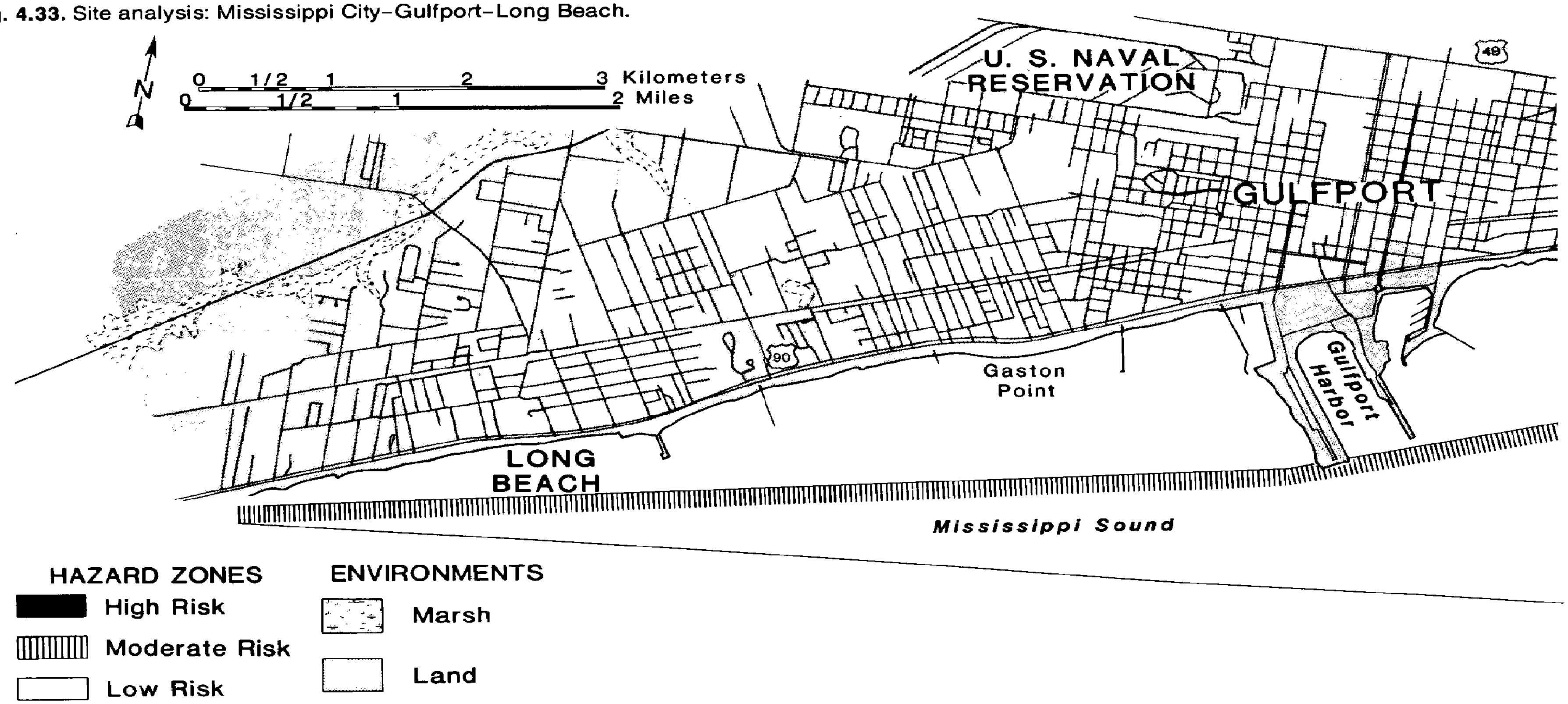
The classification shown in figures 4.32 through 4.34 is for the immediate coastal zone. This general area is difficult to assess because the risk category depends on how well the seawall and artificial beach system are maintained. If a hurricane or long-term erosion remove the beach (as is the case at Pascagoula and Waveland, for example), the property immediately in back of the wall would be more vulnerable to destruction. A property owner's best guides in site evaluation are elevation, vegetative cover, and response to recent historic hurricanes (for example, Betsy, Camille, Frederic).

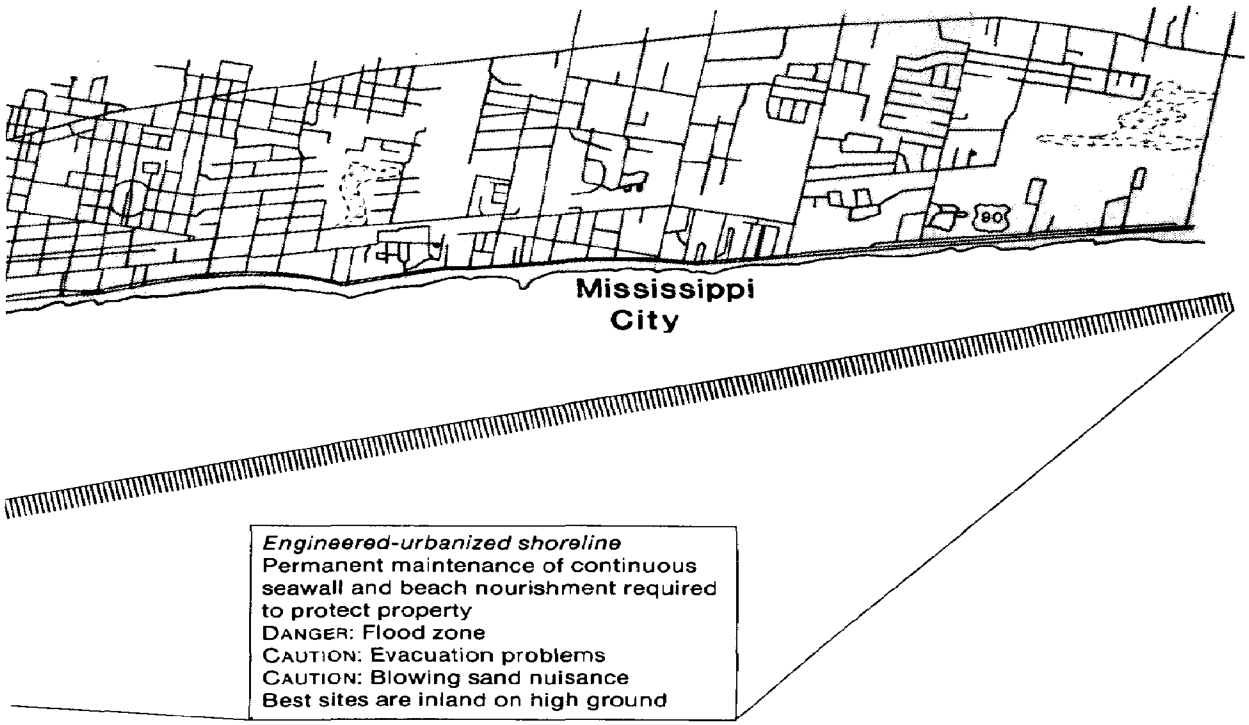
Biloxi. The city (fig. 4.32) was hit by a 16- to 19.5-foot storm surge in association with Hurricane Camille. Extensive damage resulted, especially along the waterfront. Waves came into direct contact with buildings, and the waves won! High winds, wind-blown debris, and high rainfall added to the damage. If you are new to the area since 1969, obtain copies of the U.S. Geological Survey Hydrologic Investigations Atlas HA-404 and 405 to see just how far and wide Camille's flood extended (reference 61, appendix C). The entire beach front—including all of Beach Boulevard, all of the area from Gulf to Bay east of Central High School, the land between Keegan and Auguste bayous north of Division Street, and the area east of Main Street and north of the railroad—was flooded! The routes and/or approaches to bridges to the east and north were flooded. Survivors of Camille know the value of an evacuation plan and the need to leave the area early.

Hurricane Camille may have been exceptional, but at least 4 other hurricanes had brought limited flooding and destruction during this century, which should be reason enough for the prudent to seek home sites away from the shore and on high ground. For example, such sites may be found around Keesler Air Force Base or along the ridges to the west.

Back Bay of Biloxi. Biloxi's Back Bay area (fig. 4.32) is protected from the direct attack of storms, but the storm-surge effect pushes and holds waters in embayments and bayous. High rainfall in association with hurricanes pumps more water into the system, so flooding becomes a problem. Sometimes flood levels are amplified by the constricted coastline. In 1965 Hurricane Betsy generated maximum water levels of 8.3 to 9.5 feet, and Camille's flood reached between 13 to 15 feet along most of the north shore, flood-

Fig. 4.33. Site analysis: Mississippi City–Gulfport–Long Beach.




90
Mississippi City
Engineered-urbanized shoreline
Permanent maintenance of continuous seawall and beach nourishment required to protect property
DANGER: Flood zone
CAUTION: Evacuation problems
CAUTION: Blowing sand nuisance
Best sites are inland on high ground

ing D'Iberville. A lesser threat to property adjacent to the bay is erosion. This includes bluffs that slump when undercut. Avoid areas of artificial fill, no matter how high the elevation. Choose sites that are well drained.

West of Biloxi. The flood zone here is restricted to the area on either side of U.S. 90 (fig. 4.32). Hurricane Camille's storm-surge flood level reached 19.5 feet, so areas below the 20-foot contour were flooded, for example, Beauvoir, the area south of Southern Memorial Park, and all along U.S. 90. In 1965 Hurricane Betsy flooded portions of this area.

Inland developments such as Southern Memorial Park and Edgewater Park are above flood level and may be regarded as low-risk areas if a few basic guidelines are kept in mind. First, all of the area will be subject to high winds, so construction should be wind-resistant. Second, evacuation may be required; therefore, know where shelters are located and the route to reach such shelters. Third, take all hurricane warnings seriously.

Mississippi City. This area (fig. 4.33) straddles the flood zone that extends a few hundred yards inland. Water marks left from Camille exceeded 20 feet. Selecting sites greater than 20 feet in elevation is a good first step in reducing risk as all such locations are above the flood zone and removed from the shore. Generally the safest sites are north of the railroad, but creeks and bayous provide routes for floodwaters beyond the shoreline.

Gulfport–Long Beach. This area (fig. 4.33) suffered heavy losses from Hurricane Camille, particularly along the waterfront due to storm-surge flooding. This flooding extended several blocks inland and reached maximum elevations of more than 21 feet. Wind damage was excessive throughout the region.

Sites of lowest risk are those at elevations of 20 feet or more, away from the shore. Based on Camille, a general guideline would be to locate north of the L&N railroad tracks. The Gulfport Harbor and Jones Memorial Park complex appears to have created some artificial protection for the area north of the complex. Hurricane flooding has not penetrated as far inland behind the complex as in the immediately adjacent areas. The harbor also acts as an obstruction to longshore drift and is causing local beach buildup.

Any location in this area may suffer flooding under the unusual conditions generated by hurricanes. Wind damage is almost certain, especially if no special construction precautions are taken. Be aware of your community's evacuation plan and routes. Heed hurricane warnings.

Pass Christian. Pass Christian (fig. 4.34) was more severely damaged by Hurricane Camille than the area to the east because it was in the "critical" position, just east of the storm's eye when landfall was made. Flood levels exceeded 22 feet in elevation, and essentially all routes out of Pass Christian were ultimately flooded as the entire area from Henderson Point to Bayou Portage was submerged. Pass Christian lacks the extensive area of higher elevations found to the east, or across the bay in Bay St. Louis. All sites are subject to potential flooding.

In recent years extensive development has taken place in the Henderson Point to Mallini Point area and along waterways into

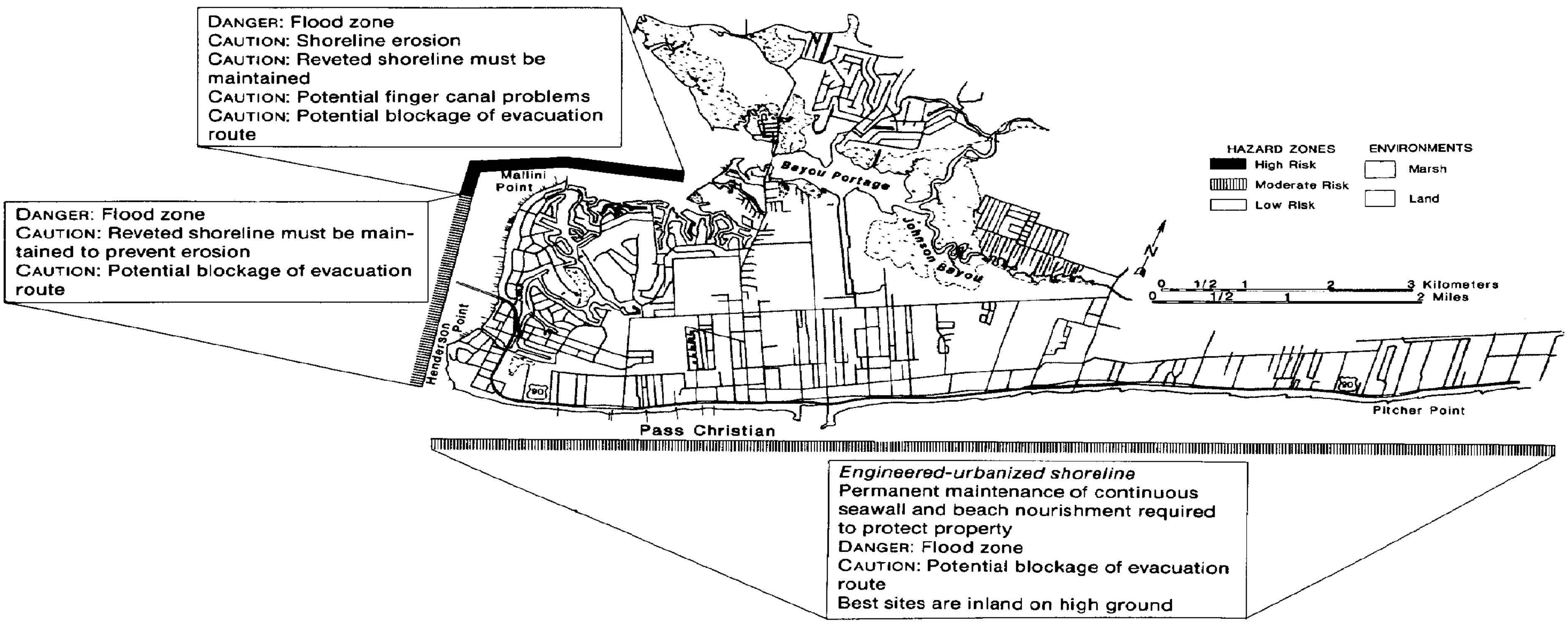


Fig. 4.34. Site analysis: Pitcher Point–Pass Christian–Bayou Portage.

Mallini Bayou. All sites in this area are in the moderate- to high-risk category. Hazards range from flooding and shoreline erosion to water quality problems.

People locating in this area should seek maximum site elevation away from the water, elevate structures, build with strong winds in mind, and take evacuation seriously.

Cat Island. The westernmost of the Mississippi barrier islands, Cat Island is unusual in its T-shape. The T is a result of the regional geologic history (reference 17, appendix C). The east-west part of the island represents earlier beach ridge formation, terminated by sinking through compaction of the underlying sediments, while erosion of the east end produced the pair of north-south spits, crossing the T.

The island is privately owned, and various alternatives for its use have been presented, including sale to the U.S. government, mining the sand resources, using it for a satellite-launching facility, or developing the island. The latter approach is highly questionable because the island is definitely high risk with respect to natural hazards. Access will always be by boat, and its position of approximately 10 miles offshore warrants early evacuation in case of a hurricane warning. In spite of this high-risk categorization and the uniqueness of the island's habitat, it was not included in the Coastal Barrier Resources Act as a result of successful lobbying by the island's owner.

Most of the island is low in elevation, marsh to around 5 feet above sea level. All of the island is in the flood zone, subject to overwash and shoreline erosion throughout its eastern end. High

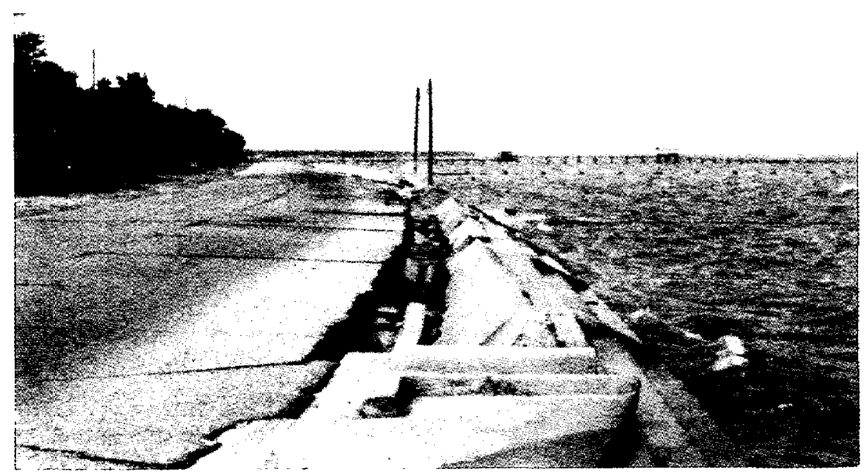


Fig. 4.35. Damaged seawall in vicinity of Bay St. Louis. Note the absence of a beach. Photo by Bill Neal.

points on the island reach 15 to 17 feet, but these are spot elevations. There is insufficient upland for development. The most appropriate use of this ephemeral island would be inclusion in the Gulf Islands National Seashore.

Hancock County

The 20-mile coast of Hancock County falls into 2 distinct divisions: the developed shore of Bay St. Louis and Waveland including the bayshore, and the contrasting extensive marsh-bayou coast extending to the Pearl River, the state boundary with Louisiana. The former is urbanized and engineered, while the latter remains in its natural state. Although Hancock County's coast is tucked behind the seaward extension of the Mississippi River Delta complex, it is not immune from the impact of storms and coastal processes.

Bay St. Louis, Waveland, Clermont Harbor–Lakeshore

The town of Bay St. Louis constructed a vertical concrete seawall in 1915 and 1920 to protect the business district. Between 1926 and 1928 the county built approximately 10 additional miles of concrete step seawall between Bayou Caddy and Joe's Bayou. For the most part a protective beach is absent (fig. 4.35). From time to time artificial beaches have been constructed but have not been maintained as permanent features. There are also some groins. Figure 4.36 classifies this shoreline as one of moderate risk. At least 6 times this century hurricanes have pushed flood levels to 10 feet above normal tide in the Bay St. Louis area, causing flooding, shoreline erosion, damage to the seawall, and extensive property damage.

Hurricane Camille (1969) was the most devastating of these storms, pushing water elevations to more than 21 feet in Bay St. Louis and more than 19 feet in Waveland where the eye of the storm made its landfall. Wind and wave destruction were widespread. The flood zone in Waveland extended to the L&N railroad tracks, 2,000 to 4,000 feet from the shore.

Bay St. Louis is centered on high ground, the edge of which extends to the shore south of the bay bridge. Flooding penetrated to Beach Boulevard, but houses on the upland above the 22-foot level suffered only wind damage. The campus of St. Stanislaus College is on somewhat lower ground and was flooded. Southwest of the campus, Camille's floodwaters penetrated 1 to 2 blocks inland and to the railroad going toward Waveland.

North of the bay bridge ramp the low-lying marsh land and all of the development north and northwest of the yacht club, centered on Dunbar Avenue and out to Cedar Point on St. Louis Bay, were flooded. Hurricane Betsy (1965) had flooded a portion of this area as well. Similarly all of the development between Bay St. Louis and the Jourdan River along Watts Bayou and Joe's Bayou was flooded.

Southwest and west of Waveland, Camille's flooding and wind damage was extensive. Clermont Harbor and Lakeshore were submerged. Intervening bayous were avenues for rapid flooding.

The experiences of Camille, Betsy, and the hurricanes of 1915,

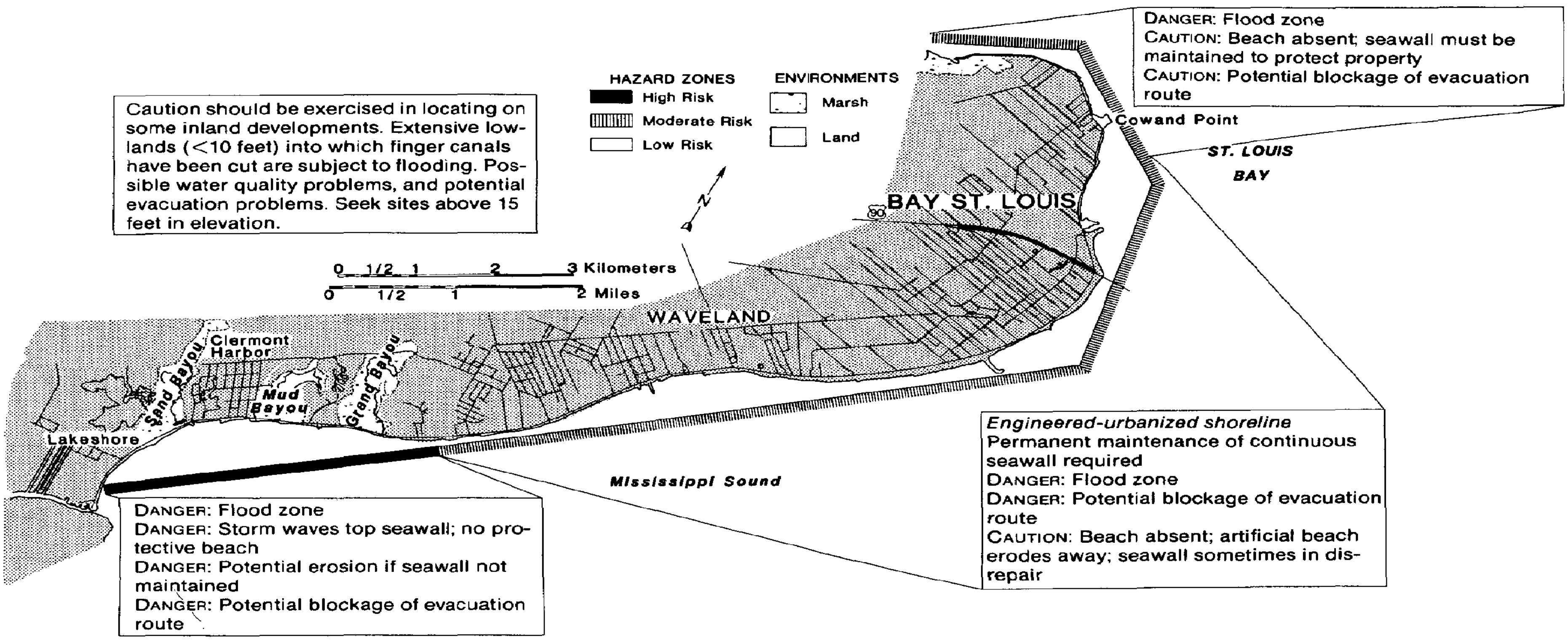


Fig. 4.36. Site analysis: Bay St. Louis–Waveland–Clermont Harbor–Lakeshore.

1916, and 1947 define the hazard zones. If you decide to locate in this general area, choose low-risk sites at elevations above 20 feet. This zone is generally north of the L&N railroad tracks and south of U.S. Highway 90, at least three-quarters of a mile east of Jackson Marsh in the Waveland area to Bay St. Louis. Wind is still a hazard in this area, and all homes should be evaluated for wind resistance.

Sites to avoid are all beach-front and bay-front property. Property with elevations under 20 feet is questionable, and elevations under 10 feet should be avoided. Bayous and marshes will be pathways for flooding, so choose locations away from these wetlands.

Finally, evacuation may be a problem, even if your property is on high ground. People living in areas such as Lakeshore, Clermont Harbor, or the low country north of these communities should evacuate early. Escape routes cross marshes or low, swampy areas that may flood the road well in advance of an approaching hurricane.

Clermont Harbor to Pearl River

The last segment of Mississippi coast is a morass of marsh, bayous, and tidal creeks. Here the slope of the land is so low that it is difficult to tell where the waters of the Gulf end and land begins. Here and there dry land interrupts the marsh where long, narrow islands like Point Clear Island rise a few feet above the marsh.

None of the area is safe for development, and lack of access precludes any likely future development.

Past reflections, future expectations

In summary, locating at the shore calls for greater prudence than in locating in an inland environment. First, less uniformity of environment exists at the shore. Topography, sediment, and vegetation change abruptly from beach, to dune, to overwash terrace, to forest, and to marsh. These systems are not stable for a very long time and change or shift in response to the rise in sea level and shoreline migration. Look to the future when selecting a site. *The future comes sooner on the coast.*

Second, coastal hazards such as hurricane winds, storm-surge flooding, wave attack, overwash, and persistent erosion are unlike anything you have experienced in the relative quiet and stability of the coastal plain or other inland, upland environments. Choose your site with such forces in mind and reinforce your construction to improve its strength to survive such forces. Expect maintenance to be more frequent and somewhat more expensive.

Third, coastal communities have their own set of dynamics, both because they are resorts and because they must respond collectively to coastal hazards. Responses to erosion, flooding, overwash, and other hazards, as well as the kind and extent of development allowed, set a course in coastal communities that is more difficult to alter than in an inland town. Expect increasing regulation and higher community costs to meet the impact of the hazards. The pattern of regulation is suggested in the next chapter.

5. The coast, land use, and the law

Development of the Gulf Coast shorelines, and those of associated bays, has been haphazard. Mississippi's urbanized shorelines must now be maintained at public expense through perpetual beach nourishment and seawall maintenance. Rapid post-Frederic redevelopment along the Alabama coast on Dauphin Island, and particularly on the Baldwin County coast, has placed a multitude of buildings in high-risk zones. The owners of these properties are likely candidates to form a voice for seawalls and beach nourishment projects along that stretch of coast.

The previous chapters demonstrate that the coastal zone is a dynamic area where land, wind, wave, and organisms interact. The resulting rapid changes are especially apparent along beaches and on barrier islands. We cannot occupy this zone without some level of interference, or without risking being affected by natural changes.

Wise land-use planning, environmental maintenance, and conservation of the coastal zone are necessary to protect the environment, but just as significant, they are necessary to protect ourselves. The ecosystem is as important to the human population as it is to a population of pelicans or a stand of sea oats. Curiously, laws are passed to protect the latter with the goal of protecting the former—sometimes from ourselves. Although we may find added regulations distasteful, it is obvious that increased control of land use at the regional level is the only way our beaches can be saved from following the New Jersey example. The guidelines for such controls must be based on the recognition of the dynamic nature of the shore. We must be willing to accept natural changes in the shore rather than adopt the philosophy of man against the sea.

Population growth, affluence, and the migration to the Sun Belt will necessitate increased regulation of the coastal zone. By analogy, as the traffic increases, more traffic laws and regulations are required to avoid the certainty of traffic jams.

The best philosophy on shoreline development is that land use should be in harmony with the natural environments and processes that constitute the system. Of course, various segments of society view the coastal zone differently. The extreme views range from untouched preservationism to unplanned, uncontrolled urbanization. Increasingly, decisions on land use are made by government under the pressure of various special-interest groups. Existing legislation is often that of compromise, satisfying the various federal, state, and local levels of the political infrastructure. We can expect that regulations will continue to be established and modified with the intention of insuring reasonable, multiple land use of the coastal zone while attempting to protect both inhabitants and the natural environment. Developers have had this expectation in the past, and in some cases it has spurred unwise development. Current and prospective owners of coastal property, especially on barrier islands, should be aware of their responsibilities under current law and expect additional regulation with respect to development and land use.

A partial list of relevant current land-use programs and regulations applicable to the Alabama-Mississippi coast follows. The explanations provided are general and introductory in nature; appendix B lists the agencies that will supply more specific and detailed information. The regulations listed here range from federal laws that protect the interests of the larger society to state and local laws and ordinances that serve the interest of the states' citizens and the local community. A review of these regulations before investing in or undertaking property development anywhere on the coast will be in your best interest. We recommend that you get in touch with the local county or municipal planning, zoning, or building department to determine state and federal permit requirements.

Coastal Barrier Resources Act of 1982

Recognizing the serious hazards, costs, and problems with federally subsidized development of barrier islands, the United States Congress passed the *Coastal Barrier Resources Act* (Public Law 97-348) in October 1982. The purpose of this federal law is to minimize loss of human life and property, wasteful expenditure of federal taxes, and damage to fish, wildlife, and other natural resources from incompatible development along the Atlantic and Gulf coasts. The act covers 190 designated areas, covering 700 miles of undeveloped barrier beaches in the United States.

Specifically, the act prohibits the expenditures of federal funds (including loans and grants) for the construction of infrastructures that encourage barrier island development, for example, roads, bridges, water supply systems, waste water treatment systems, and erosion control projects. Any new structure built on these designated barrier islands (as of October 1, 1983) is not eligible for federal flood insurance. Certain activities and expenditures under the act are permissible. The act does not prohibit private development on the designated barrier islands but passes the risks and costs of development from taxpayers to owners. All applicable federal, state, and local permits still must be obtained before any development begins in the designated areas.

The Coastal Barrier Resources Act affects only a small portion of the Alabama-Mississippi coast, covering approximately 23 miles of Gulf beaches (table 5.1). For exact boundaries of the designated areas, get in touch with local city or county planning departments or order the map for the area needed from the E-NCIC as listed in table 5.1.

The National Flood Insurance Program

Some flood insurance facts

One of the most significant legal pressures applied to encourage land-use planning and management in the coastal zone is the National Flood Insurance Program (NFIP). The *National Flood Insurance Act of 1968* (P.L. 90-448) as amended by the *Flood Disaster Protection Act of 1973* (P.L. 92-234) was passed to encourage prudent land-use planning and to minimize property damage in flood-prone areas like barrier beaches. Local commu-

Table 5.1. Alabama-Mississippi barrier coast affected by Coastal Barrier Resources Act

Area	Map number	Miles of beach
Alabama		
Mobile Point unit	Q01	3.5
Pelican Island	Q01A	1.75
Dauphin Island	Q02	9
Mississippi		
Round Island	R01	1.25
Belle Fontaine Point	R01A	1.25
Deer Island	R02	4
Cat Island	R03	2

Source: Public Law 97-348.
Note: The Coastal Barrier Resources System maps (36" × 42") are available for $3.25 each from the Eastern-National Cartographic Information Center, U.S. Geological Survey, 536 National Center, Reston, VA 22092. Order by title and map number.

nities must adopt ordinances to reduce future flood risks in order to qualify for the National Flood Insurance Program. The NFIP provides an opportunity for property owners to purchase flood insurance that generally is not available from private insurance companies.

The initiative for qualifying for the program rests with the community by contacting the Federal Emergency Management Agency (FEMA). FEMA will provide the community with a Flood Hazard Boundary Map (FHBM). Any community may join the National Flood Insurance Program provided that it requires development permits for all proposed construction and other development within the flood zone and ensures that construction materials and techniques are used to minimize potential flood damage. At this point the community is in the "Emergency Phase" of the NFIP. The federal government makes a limited amount of flood insurance coverage available, charging subsidized premium rates for all existing structures and/or their contents, regardless of the flood risk.

FEMA may provide a more detailed Flood Insurance Rate Map (FIRM) indicating flood elevations and flood-hazard zones, including velocity zones (V-zones) for coastal areas where wave action is an additional hazard during flooding. The FIRM identifies Base Flood Elevations (BFE), establishes special flood hazard zones, and provides a basis for floodplain management and establishing insurance rates.

To enter the Regular Program phase of the NFIP, the community must adopt and enforce floodplain management ordinances that at least meet the minimum requirements for flood hazard reduction as set by FEMA. The advantage of entering the Regular Program is that increased insurance coverage is made available, and new development will be more hazard-resistant. All new structures and substantially improved preexisting structures will be rated on an actual risk (actuarial) basis, which may mean higher insurance rates in coastal high-hazard areas but generally results in a savings for development within numbered A-zones (areas flooded in a 100-year coastal flood but less subject to turbulent wave action).

FEMA maps use the "100-year flood" as the base flood elevation to establish regulatory requirements. People unfamiliar with hydrologic data sometimes mistakenly take the "100-year flood" to mean a flood that occurs once every 100 years. In fact, a flood of this magnitude could occur in successive years, or twice in one year, and so on. The flooding in Jackson, Mississippi, that has occurred over the past few years illustrates this point. If we think of a 100-year flood as a level of flooding having a 1 percent statistical probability of occurring in any given year, then during the life of a house within this zone that has a 30-year mortgage, there is a 26 percent probability that the property will be flooded. The chances of your property being flooded becomes 1 in 4, rather than 1 in 100. Having flood insurance makes good sense.

In V-zones, new structures will be evaluated on their potential to withstand the impact of wave action, a risk factor over and above the flood elevation. When your insurance agent submits an application for a building within a flood hazard area, a certification of structural design must accompany the application. For buildings within a V-zone the elevations are adjusted, usually an additional 2 to 6 feet above stillwater flood levels, to minimize wave damage. The insurance rates are also higher in these zones.

The insurance rate structure provides incentives of lower rates if buildings are elevated above the minimum federal requirements. Flood insurance coverage is provided for structural damage as well as contents.

Most coastal communities with barrier beaches are now covered under the Regular Program. To determine if your community is in the NFIP and for additional information on the insurance, contact your local property agent or call the NFIP's servicing contractor (phone: [800] 638–6620) or the NFIP State Assistance Office (phone: Alabama [205] 832–6963; Mississippi [601] 982–6376). For more information, request a copy of "Questions and Answers on the National Flood Insurance Program" from FEMA (reference 85, appendix C).

Before buying or building a structure on a barrier beach, an individual should ask certain basic questions:

1. Is the community I'm located in covered by the Emergency or Regular Phase of the National Flood Insurance Program?
2. Is my building site located in the designated areas of the Coastal Barrier Resources Act, where no federal flood insurance on new structures was to be available after October 1, 1983? (See Table 5.1.)
3. Is my building site above the 100-year flood level? Is the site located in a V-zone? V-zones are high-hazard areas and pose serious problems.
4. What are the minimum elevation and structural requirements for my building?
5. What are the limits of coverage?

Make sure your county is enforcing the ordinance requiring minimum construction elevations. After Hurricane Frederic (1979) a number of homeowners from Santa Rosa County, Florida, whose houses were flooded, put in claims for federal flood insurance. It turned out that on direct order from the county commissioners, the elevation requirements for insurance were not being enforced by the county. One woman who had paid $158.00 a year for her insurance discovered she should have been paying over $13,000 a year because her house was 5 feet below the 100-year flood level. Prior to construction, her house plans had been approved by the county and no mention was made of the elevation problem. Before payment of her $17,000 claim, the National Flood Insurance Program subtracted the correct $13,000 premium. Later, all parties agreed on a lower but still substantial figure for flood insurance premiums. More than 20 people in the National Flood Insurance Program in the local community were forced to continue paying exorbitant insurance premiums for buildings built below the required elevation because the banks that held their mortgages insisted upon it. This problem came about because county officials said nothing about flood elevations when issuing building permits. The county commissioners fared very poorly in the next election!

Most lending institutions and community planning, zoning, and building departments will be aware of the flood insurance regulations and can provide assistance. It would be wise to confirm such information with appropriate insurance representatives. All insurance companies charge the same rates for federal flood insurance policies.

The National Flood Insurance Program states its goal as "to . . . encourage State and local governments to make appropriate land use adjustments and to constrict the development of land which is exposed to flood damage and minimize damage caused by flood losses" and "to . . . guide the development of proposed future construction, where practical, away from locations which are threatened by flood hazard." To date, development in flood-hazard areas continues at a rapid rate.

FEMA's elevation requirements have encouraged buildings designed to withstand the flood hazard. Revision of minimum flood elevations in the V-zones of coastal counties takes into account the additional hazard of storm waves atop stillwater flood levels. Existing FEMA regulations stipulate protection of "dunes and vegetation" in the V-zones, but implementation of this requirement by the local communities has not always been strong. The existing requirements of the NFIP do not address other hazards of "migrating" shorelines, for example, shoreline erosion or inlet migration. Thus, buildings may meet the minimum FEMA elevation requirements, but at the same time they can be located near highly exposed and eroding shorelines. In addition to recognizing the flood hazard, there is a need to incorporate location and structural codes that reflect migrating shorelines, hurricane winds, wave uplift, horizontal pressures and scouring to minimize the loss of structures and tax dollars that have supported the insurance program.

In the past the National Flood Insurance Program has been subsidized and has grown to become a large federal liability. As of August 31, 1981, more than 1.918 *million* flood insurance policies valued at $97.972 *billion* had been sold nationwide. Coastal counties had 1.165 million of these policies valued at $64.667 billion. In more local terms, Mobile County had flood insurance policies valued at over $97.7 million in 1978. Claims paid in 1979, mostly due to Hurricane Frederic, exceeded $10.7 million. The impact of Hurricane Frederic on the NFIP is reflected in another statistic, the cost/loss per policy in velocity zones. During 1978–79 the average premium for federal flood insurance policies located in all velocity zones was $131 a year while the average expense and loss per policy in these areas was $422 a year, due mainly to Frederic. Such losses have encouraged the addition of wave heights to flood elevations, and as a result insurance rates have been raised substantially.

Recognition of natural hazards and tax subsidy problems provided the rationale for Congress to pass the Coastal Barrier Resources Act in 1982. The act prohibits the sale of flood insurance for new construction or substantial improvements after October 1, 1983, on certain designated undeveloped barrier islands and ended federal assistance for any infrastructures for development (for example, bridges, highways, water-treatment systems). There is an urgent national need to address the problems of developed or developing barrier beaches which were not covered in the Coastal Barrier Resources Act in order to minimize hazards to human lives and loss of property in these areas. An incentive program to encourage sound land-use planning, limit density of development, improve hurricane evacuation, and allow relocation of damaged structures after hurricanes needs to be developed before a disaster strikes the coast.

Hurricane evacuation

The Disaster Relief Act of 1974 authorized FEMA to establish disaster preparedness plans in cooperation with local communities and states. Alabama (Civil Defense Act of 1955; Governor's executive order No. 14, 6/14/71) and Mississippi (State Code 33-15) already had such plans in place, which are now coordinated with the federal act as well as local ordinances. Hurricane evacuation remains a critical problem on barrier islands and coastal floodplains. Due to heavy concentrations of population in areas of low elevation, narrow roads and vulnerable bridges and causeways, plus limited hurricane warning capability (possibly 12 hours or less), it may be difficult to evacuate all people prior to a hurricane.

Coastal communities have formulated detailed hurricane evacuation plans. You should check for hurricane evacuation plans with the county Civil Defense or Disaster Preparedness officer and find out if any potential evacuation problems will exist during a hurricane. These offices can provide information on the location of hurricane evacuation shelters and are responsible for providing emergency and relocation assistance after hurricanes. The Civil Defense Office also can provide information on expected losses from hurricanes.

Coastal zone management

The federal Coastal Zone Management Act of 1972 (P.L. 92-583) generated an effort by most coastal states to manage their shorelines and conserve a vital national resource. Key requirements of the act are coastal land-use planning based on land classification and on identification and protection of critical areas.

The federal requirements were broad enough to allow each state to establish management regulations through its own legislative process. The result is a variety of approaches to actual management. Alabama and Mississippi are examples of the contrast in approach and the problems that can arise.

Mississippi

The backbone of this state's management program is the Wetlands Protection Law of 1973 and the Mississippi Marine Resource Council enabling legislation, under the umbrella of the Mississippi Coastal Program (MCP; reference 89, appendix C; see also appendix B). The Bureau of Marine Resources of the Department of Wildlife Conservation is the state agency charged with enforcement of the Mississippi Coastal Program.

Some of the goals of the program are "to provide for reasonable industrial expansion in the coastal area" but at the same time "to conserve the resources of the coastal area for this and succeeding generations," "to encourage the preservation of natural scenic qualities," and "to assist local governments in the provision of public facilities and services in a manner consistent with the coastal program."

Another important objective is to consolidate state policy in the coastal area and simplify the process of applying for and obtaining various types of permits and licenses. "One-stop permitting" is achieved through the Bureau of Marine Resources, which acts as a clearinghouse for permits. For example, suppose you wish to construct a dock on your waterfront that will involve some dredge and fill. You would need permits from both the MCP and the Army Corps of Engineers. The "one-stop permitting" process through the Bureau of Marine Resources will meet both application requirements through a single set of forms. The processing and issuing of permits is coordinated, and review or processing is reduced to the shortest practical time.

Before any activity in the coastal zone (for example, construction, dredge and fill, removal of vegetation, installation of septic or water treatment systems, sediment or water discharge) is undertaken, you should check with the Bureau of Marine Resources (see appendix B). While the BMR is the primary administrator of the coastal program, the Bureau of Pollution Control and Land and Water Resources (also in the Department of Natural Resources) and the Department of Archives and History also are responsible for monitoring decisions that affect the coastal area of Hancock, Harrison, and Jackson counties and all coastal waters.

The Mississippi Coastal Program has been relatively free of controversy. The fact that the Mississippi coast is already highly urbanized and that the barrier islands are part of the National Seashore has resulted in less conflict over residential development. Deer Island is one of the exceptions (see chapter 4). Perhaps the biggest problem facing the program is the pressure to industrialize coastal areas that are now wetlands. Such land is often viewed as worthless in its present state, a prime target for dredge and fill to create industrial parks. The test of the coastal management program will be whether or not the wetland resource is protected.

Alabama

In contrast, the coastal management program in Alabama was based on new legislation, stimulated by the federal program. The Alabama Coastal Area Program (ACAMP) was approved in 1979 (reference 87, appendix C). Act 534, the Alabama Coastal Area Act, established the Coastal Area Board (CAB) with the mandate to develop a comprehensive management program with rules and regulations. The same act established the *coastal area* from the contiguous 10-foot inland contour to the seaward limit of the state's territorial water (3 nautical miles), including coastal islands. In 1982 the Alabama legislature created the new Department of Environmental Management (ADEM), and in October, 1982, the functions of the CAB were transferred to ADEM and the Department of Economic and Community Affairs (DECA). ADEM is charged with all coastal permitting and regulation, whereas ADECA includes planning and nonpermit/nonregulatory functions.

The purpose of the Alabama Coastal Area Act is "to promote, improve and safeguard the lands and waters in the coastal areas . . . through a comprehensive and cooperative program designed to preserve, enhance and develop such valuable resources" for the future. Resources include "natural, commercial, recreation, industrial and aesthetic." The fragility of the natural ecosystem and the need for balanced development are recognized.

The 1982 creation of ADEM was an effort to streamline the permitting process and consolidate the environmental regulatory programs. One-stop permitting is achieved through the Department of Environmental Management. Before you engage in any activity that will alter the coastal zone system, you must apply for the necessary permits through ADEM (see appendix B).

Obtain a copy of "Building in the Coastal Counties: A Guide to the Permitting Process with Special Emphasis on the Coastal Areas" (reference 88, appendix C) for specific information. One of the most important requirements is that construction must be 40 feet landward of the primary dune line crest.

Controversy. Almost from its inception the Coastal Area Board (CAB) was under fire from man and nature. Legislative attempts to change the program and Hurricane Frederic created such uncertainty that it is debatable whether the CAB ever reached its design effectiveness. About the time it defined the primary dune line (to enforce the mandated 40 feet of setback behind such a line), Frederic washed the dunes away! At the time of this writing some state officials still regard that now nonexistent rampart as the legislated line of permitting authority. The dune line must have been chosen because of its protective role. To insist on the letter of the law when real protective dunes no longer exist, and are likely to reestablish landward of this former position (see chapter 2, sea-level rise), is like being in the crowd that watched the king in his invisible clothes, afraid to tell him of his nakedness. The beach houses rebuilt after Frederic behind these imaginary dunes are just as naked (fig. 5.1).

Although the formation of ADEM and the division of the Coastal Area Board functions between the new agency and the ADECA were designed in part to streamline the permitting process and consolidate coastal and other environmental regulatory programs, the transition year 1982–1983 was one of increasing controversy and a breakdown in regulatory permitting rather than increased efficiency or prudent land use. As the CAB held its final meeting, it was clear that the oil and gas industry was not being monitored closely. The admitted illegal dumping of drilling wastes into Mobile Bay was an embarrassment to all. On the Fort Morgan Peninsula developers of condos were bulldozing primary dunes and "rebuilding" them closer to the water. Dune sands were being removed to fill wetland for a sewage plant. These activities were going on without all of the necessary permits. No certificate of consistency was issued for the Fort Morgan development as called for by ACAMP. U.S. Capitol Corporation, builder of a 300-unit complex on Highway 180, was cited for code violations by Baldwin County regarding fire-resistance requirements. Construction in the wetland was halted by the U.S. Army Corps of Engineers because of violations of the Clean Water Act. Some wells in this area were already known to be polluted, and groundwater supply is limited.

In April 1983 a civil suit was filed against ADEM contending that the department had failed to enforce regulations of the Coastal Area Management Program. In May the news broke that federal funds were being withheld because of questions about how Alabama was handling its program. The federal officials contended that the CAB had been the permitting agency, but the director of

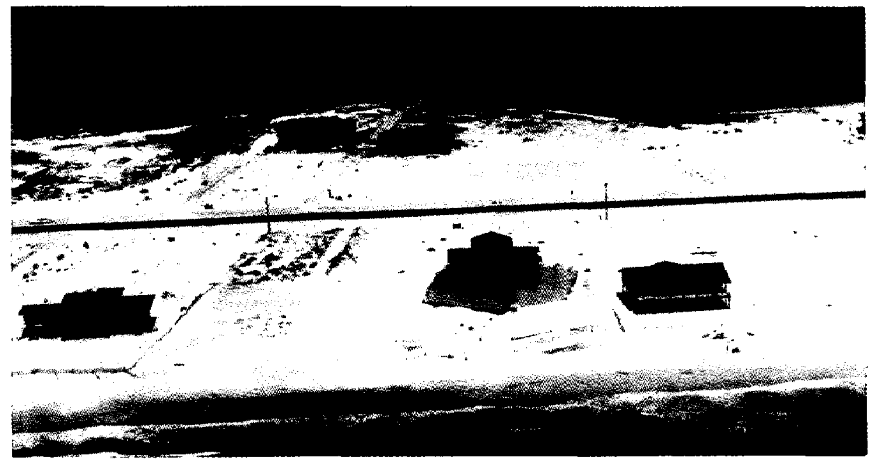


Fig. 5.1. Post-Frederic construction, West Beach, Alabama. Note the absence of any dune line. The original dune line governing the setback requirement was destroyed by the hurricane. Photo by Bill Neal.

ADEM contended it was not, that it lacked the proper technical expertise or staff to make decisions of a technical nature, and that the county commissioners are authorized under CAMP to issue permits (where the counties get their technical expertise is unclear). In June, ADEM closed its Mobile office and the media reported the coastal management program to be "broke." An editorial in the *Azalea City News* lamented that "this program has become erroneously interpreted, inadequately enforced, incompetently managed to the point of bankruptcy." In August, Coastal Environmental Alliance, Inc., was formed because its members felt that the Mobile area had lost its ability to police its environment with the loss of the Coastal Area Board. The Theodore Industrial Complex outfall line and its potential pollution impact on important oyster beds was their first case in point. However, in 1984, ADEM opened another office in Mobile, further illustrating the story of change.

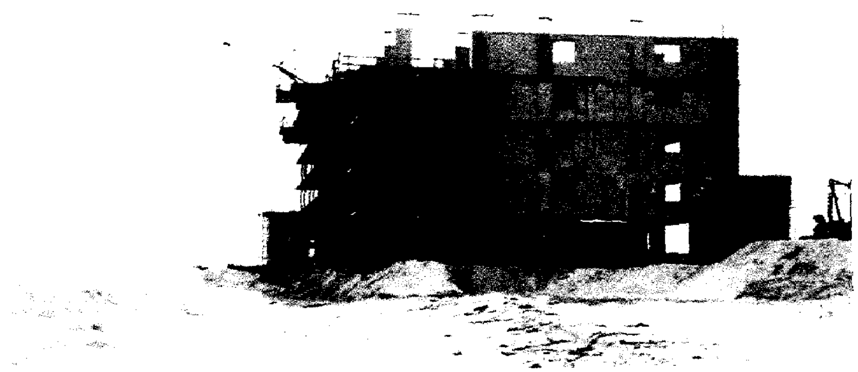


Fig. 5.2. Early construction phase of Lei Lani Towers on Perdido Key. To paraphrase a popular expression: "Where's the beach?" Photo by Eugene Brannan, Freelance Photography Unlimited, © 1983.

Although some of these statements are charged with emotionalism, they bear seeds of truth. A sharp eye was not being kept on the coast, and problems were spreading. In August, FEMA directed the Baldwin County Commission to issue stop-work orders on 7 beach-front developments. Romar House (later excluded from the order), Perdido Dunes, Lei Lani Towers (fig. 5.2), Winddrift Condominiums, Perdido Quay, and Perdido Hotel in the Alabama Point–Perdido Key area, and the Surf Club and Marina in the Fort Morgan area were believed to be in violation of FEMA flood insurance requirements, particularly in the significant alteration of dunes in the designated velocity zones (V-zones). The resulting hearings and news reports again put ADEM in the spotlight. (Interested readers might wish to contact the *Robertsdale Independent*, Robertsdale, Alabama, for a series of informative articles by Mike Williams.) By December 1983, ADEM found it necessary to impose a moratorium on development for approximately 2 weeks. The controversy and the law suits continue.

Perhaps the programs designed to protect are in fact part of the problem. Did the knowledge of the coming federal Coastal Barrier Resources Act spur developers to accelerate building on previously undeveloped properties? It is quite likely. Did the state Coastal Area Act intend the primary dune line as it existed prior to Hurricane Frederic (1979) to be the definitive line on which all future development was to be based? Or did the law intend for the setback line to fluctuate through time, as the dune line fluctuates? If the line is rigid, the law will be defeated by a rising sea level. If we legally define dunes as something they are not in the natural system, then lawyers will defeat the law. At one point in the controversy, the setback requirement in the absence of a dune was 250 feet inland of the first vegetation at the back of the beach. The assumption apparently is that the primary dune crest will reform approximately in keeping with legal requirements. In still another case the permit to build was issued with the requirement that an artificial dune be constructed and maintained to meet the setback requirement. Until such variances cease, the Coastal Area Program will not serve its defined purpose.

Figure 5.2 is a clear illustration of the real situation. Cutting away all discussion of where the dune may be forming, or what the setback was supposed to be, or what the plan looked like on paper, or who said what, when, and to whom, the structure is being built at the edge of the surf! The building site was sand bulldozed into the position shown at the water's edge, with additional sand pushed up in front of the construction to keep it from flooding while being built. The "erosion problem" is "built in" here just as sure as are the kitchen cabinets.

This development in the V-zone is a replay of what has happened again and again in other states. A recent example from South Carolina is the blueprint for what is likely to happen at Lei Lani Towers and its sisters near the surf. Condominiums were recently built near the ocean at the Wild Dunes Beach and Racquet Club on the Isle of Palms. Even during construction, beach sand was being bulldozed and packed in front of the buildings to protect them from flooding. Waves gnawed at these artificial barriers. In the words of a local resident who watched the development: "Residents purchased condominiums that were built too close to the ocean. They were so enamored of their close-range seascape that they risked having sea water spill over their sundecks . . . regular and predictable erosion cycles so familiar to coastal ecologists were not so familiar to the condominium purchasers. They coveted too strongly their own vista. It blinded them."

Almost immediately the new owners found their property in trouble. They petitioned for a riprap seawall and sought permits for such construction. Although their island neighbors protested, public officials allowed the engineering solution. One island resident noted that either the condominiums would be saved and the beach lost, or vice versa, but it could not be both ways. The mayor (like a good politician and ignoring an existing wall with no beach at high tide) said you can have it both ways. The developer made no bones about it: the revetment was to save the buildings, not the beach.

In issuing the permit, however, the state coastal management agency hung a millstone around the necks of the condominium owners. The permit requires that the homeowners and club keep the riprap covered with sand and the beach in front of the wall nourished. If enforced, this requirement will be a heavy financial burden to pay for the ocean vista that is still not worry-free!

Clearly, in all coastal states, there is a gap between what is to be learned from coastal experience/coastal science, how such experience may be fruitfully applied in coastal regulation, and in what coastal political arena such regulation is to take place. Since science, politics, business, and bureaucracy seem destined to meet at the shore, perhaps future ADEM meetings and hearings should be scheduled at the Lei Lani during storms, preferably where all participants can see the beach, or lack of it, during discussions.

Building codes

Coastal dynamics preclude shoreline and island development patterned after traditional inland styles. A one-story, ranch-style house at the back of the beach will block wind transport of sand, interfere with overwash, and ultimately behave as a seawall before being destroyed in its turn by storm waves and flooding. This traditional design in this dynamic zone would have a much shorter life expectancy than the same house in an inland location. The services for this house and many like it (for example, electric lines, gas mains, water lines), the sewage generated, and the roads, bridges, and service structures required for such development will exceed the carrying capacity of a barrier island or beach dune system much quicker than for a similar inland community development. The resulting damage to the environment through pollution, loss of habitat, stabilization structures, and the like removes the amenities that most shore dwellers originally came to enjoy. Not only is aesthetic value lost, but the risk from coastal hazards is magnified.

Building codes and zoning ordinances provide a means of controlling building location and design and set minimum standards for materials and construction to reduce the likelihood of property damage or loss to natural processes. Most progressive communities require that new construction adhere to the provisions of a recognized building code. If you plan to build in an area that does not follow such a code, you would be wise to insist that your builder do so to meet your requirements.

Local building officials in storm areas often adopt national codes that contain building requirements for protection against high wind and water. Compiled by knowledgeable engineers, code enforcement officials, and architects, these codes regulate the design and construction of buildings and the quality of building materials.

The Standard Building Code (formerly the Southern Standard Building Code; reference 113, appendix C) is the building code in general use along the Gulf Coast. This code has certain hurricane-resistance requirements such as continuity, stability, and anchorage, all related to calculated reference wind speed as modified by height above ground and building shape factors to determine the design load.

Individual counties and coastal communities often adopt amendments or modifications to this code, particularly for structures placed on the floodplain or in the V-zone. These supplements have more stringent requirements for piling size, piling support, depth of piling embedment, framing, plumbing, and mechanical and electrical installations to improve wind and flood resistance.

It is emphasized that the purpose of these codes is to provide *minimum* standards to safeguard lives, health, and property. Communities have the right to strengthen the adopted code in order to improve it or make it more stringent. As a result, numerous communities do have specifications that go beyond the Standard Building Code. We recommend such strengthening amendments as those suggested by the Florida Department of Natural Resources in their "Recommendations for a Coastal Construction Building Code" (reference 125, appendix C). Check with your local building inspector to determine the specific code for your area.

Individuals can and should insist on designs and materials that go beyond the *minimum* code requirements (see chapter 6 on construction). Sanibel Island, Florida, has adopted one of the better codes on the Gulf Coast with respect to coastal construction.

Mobile home regulations

Mobile homes differ in construction and anchorage from permanent structures. The design, shape, lightweight construction materials, and other characteristics required for mobility, and for staying within axle-weight limits, create a unique set of potential problems for residents of these dwellings. Because of their thinner walls, for example, mobile homes are more vulnerable than permanent homes to wind and wind-borne projectiles. Thus, some coastal states and communities have separate requirements for mobile homes. The mobile home owner should check with the appropriate authority.

Mobile home anchorage may be regulated by local ordinance. Tiedowns should be required to make the structure more stable against wind stress (for recommendations, see the section on mobile homes in chapter 6). Violations of anchorage or foundation regulations may go undetected unless there are a sufficient number of conscientious inspectors to monitor trailer courts. One poorly anchored mobile home can severely damage adjacent homes whose owners abided by sound construction practice. Some operators or managers of mobile home parks are alert to such problems and see that they are corrected; others simply collect the rent.

The spacing of mobile homes also may be regulated by local ordinance. Providing residents with open space between homes, this type of ordinance preserves some aesthetic value for a neighborhood and helps to maintain a healthier environment. For example, if mobile home septic tanks are closely spaced, there is the potential for groundwater or surface water pollution. Similarly, if mobile homes are built too close to finger canals, canal water may become polluted.

Check with your city or county building inspector's office about mobile home regulations.

Water quality and waste disposal

Protecting the water resources of barrier coasts as well as the bay coasts is essential for safeguarding the various uses of the coast. Fisheries, all forms of water recreation, and the general ecosystem depend on high-quality surface waters. Potable water supply is drawn mainly from groundwater that also must be of high quality. As noted in chapter 4, water resources are being threatened, and existing pollution is costly to both local communities and the state. When shellfishing waters are closed or the health of local residents is threatened, the loss is more than economic.

Water quality is measured by fecal coliform count. Fecal coliform is a type of bacteria found in human wastes, and its abundance is a good measure of the extent of pollution.

The Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500), as administered by the U.S. Environmental Protection Agency in cooperation with state agencies, control any type of land use that generates, or may generate, water pollution. The dredging and filling of wetlands and water bodies is regulated through the U.S. Army Corps of Engineers (see appendix B, under Dredging, filling, and construction in coastal waterways, and Sanitation and septic system permits). The *Marine Protection, Research and Sanctuaries Act of 1972* (P.L. 92-532) regulates dumping into ocean water. The *Water Resources Development Act of 1974* (P.L. 93-251) also provides for comprehensive coastal zone planning.

At the state and local levels the coastal zone management agencies (ADEM in Alabama; Bureau of Marine Resources in Mississippi) and the municipal or county health departments have the primary permitting authority with respect to activities that may affect water quality. Before drilling a well or installing a septic system, check with these state and local offices.

Endangered species

The *Endangered Species Act of 1973* protects several animals common to the Gulf Coast. In particular, whales, the West Indian Manatee, the American alligator, Loggerhead and Green Sea Turtles, the Atlantic Ridley, Hawksbill, and Leatherback turtles are covered by the act. The penalty for intentionally shooting, killing, or harming any endangered, threatened, or protected animal is severe. Consult your state's conservation and resources offices (see appendix B, Wildlife).

6. Building or buying a house near the beach

Real estate roulette: protecting your bet

In reading this book you may conclude that the authors are at cross-purposes. On the one hand, we recommend that development of barriers and beach front be avoided because of the risks and dangers attendant to building on the coast. On the other hand, we provide you with a guide to evaluate the risks; and in this chapter we describe what type of structure is best to buy or build near the beach.

This apparent contradiction is more rational than it might seem at first. For those who will heed the warning, we describe the risks of owning shore-front property. For those who decide that the satisfaction of living on the edge of the sea is worth the risk, we provide some guidelines to reduce but not eliminate those risks.

Reality dictates that development will not stop. Some individuals will always be willing to gamble their real wealth to be near the shore. For those who elect to play this game of real estate roulette, we provide some advice as to how to place their chips in the game. We do *not* recommend that you play the game!

If you want to learn more about construction near the beach, we recommend the book *Coastal Design: A Guide for Builders, Planners, and Home Owners* (Van Nostrand Reinhold, 1983), which gives more detail on coastal construction and supplements this volume. In addition, the Federal Emergency Management Agency's *Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas* is an excellent guide to coastal construction and additional reference material (see references 107 and 108, appendix C).

Coastal realty versus coastal reality

Coastal property is not the same as inland property. Do not approach it as if you were buying a lot in a developed woodland of northern Alabama or a subdivided farm field in the Coastal Plain. The previous chapters illustrate that the shores of the Gulf Coast, especially the barrier islands, are composed of variable environments and are subjected to nature's most powerful and persistent forces. The reality of the coast is its dynamic character. Property lines are an artificial grid superimposed on a changing land and sea that know no such boundaries. If you choose to place yourself or others in this zone, prudence is in order.

A quick glance at the architecture of the structures on the Alabama-Mississippi coast provides convincing evidence that the reality of coastal processes was rarely considered in their construction. Apparently the sea view and aesthetics were primary considerations. Except for meeting minimal building requirements, no further thought seems to have been given to the safety of many of these buildings. The failure to follow a few basic architectural guidelines that recognize this reality will have disastrous results in the next major storm. Gamblers usually try to stack the odds as much in their favor as possible; the same should be true when designing to live with nature.

Life's important decisions are based on an evaluation of the facts. Few of us buy goods, choose a career, take legal, financial, or medical actions without first evaluating the facts and seeking advice. In the case of coastal property 2 general aspects should be evaluated: site safety and the integrity of the structure relative to the forces to which it will be subjected.

A guide to evaluating the site(s) of your interest on the Gulf Coast and bay shorelines is presented in chapter 4, along with hazard evaluation maps. The remainder of this chapter focuses on the structure itself, whether cottage or condominium.

The structure: concept of balanced risk

A certain probability of failure for any structure exists within the constraints of economy and environment. The objective of building design is to create a structure that is both economically feasible and functionally reliable. A house must be affordable and have a reasonable life expectancy free of being damaged, destroyed, or wearing out. To obtain such a house, a balance must be achieved among financial, structural, environmental, and other conditions. Most of these conditions are "higher" on the coast, for example, higher property values, higher desire for aesthetics, higher environmental sensitivity, higher chance of storms and other hazards.

The individual who builds or buys a home in an exposed area should fully comprehend the risks involved, the likelihood of harm to home or family. The risks should then be weighed against the benefits to be derived from the residence. Similarly the developer building a motel should weigh the possibility of destruction and death during a hurricane versus the money or other advantages to be gained from such a building. Then and only then should construction proceed. For both the homeowner and the developer, proper construction and location reduce the risks involved.

The concept of balanced risk should take into account the following fundamental considerations:

1. Construction must be economically feasible.
2. Therefore, ultimate and total safety is not obtainable for most homeowners on the coast.
3. A coastal structure, exposed to high winds, waves, or flooding should be stronger than a structure built inland.
4. A building with a planned long life, such as a year-round residence, should be stronger than a building with a planned short life, such as a mobile home.
5. A building with high occupancy, such as an apartment building, should be safer than a building with low occupancy, such as a single-family dwelling.
6. A building that houses elderly or sick people should be safer than a building housing able-bodied people.

Structures can be designed and built to resist all but the largest storms and still be within reasonable economic limits.

Structural engineering is the designing and constructing of buildings to withstand the forces of nature. It is based on a knowledge of the forces to which the structures will be subjected and an understanding of the strength of building materials. The effectiveness of structural engineering design was reflected in the aftermath of Cyclone (hurricane) Tracy that struck Darwin, Australia, in 1974. Housing that was not based on structural engineering principles suffered 70 percent destruction and 20 percent seriously damaged; that is, only 10 percent of such housing weathered the storm. In contrast, more than 70 percent of the structurally engineered large commercial, government, and industrial buildings came through with little or no damage, and less than 5 percent of such structures suffered destruction. Because housing accounts for more than half of the capital cost of the buildings in Queensland, the state government there established a building code that requires standardized structural engineering for houses in hurricane-prone areas. This improvement has been achieved with little increase in construction and design costs.

Coastal forces: design requirements

Hurricanes, with their associated high winds and storm surge topped by large waves, are the most destructive of the forces to be reckoned with on the coast. Winter storms, however, also can be devastating. Figure 6.1 illustrates the effects of hurricane forces on houses and other buildings.

Hurricane winds

Hurricane winds can be evaluated in terms of the pressure they exert. A 100-mph wind exerts a pressure or force of about 40 pounds per square foot on a flat surface. The pressure varies with the square of the velocity. For example, a wind of 190-mph velocity exerts a force of 144 pounds per square foot. This force is modified by several factors that must be considered in designing a building. For instance, the effect on a round surface, such as that of a sphere or cylinder, is less than the effect on a flat surface. Also, winds increase with height above ground, so a tall structure is subject to greater pressure than a low structure.

A house or building designed for inland areas is built primarily to resist vertical loads. It is assumed that the foundation and framing must support the load of the walls, floor, and roof, and relatively insignificant wind forces.

A well-built house in a hurricane-prone area, however, must be constructed to withstand a variety of strong wind forces that may come from any direction. Although many people think that wind damage is caused by uniform horizontal pressures (lateral loads), most damage, in fact, is caused by uplift (vertical) suctional (pressure outward from surface), and torsional (twisting) forces. High horizontal pressure on the windward side is accompanied by suction on the leeward side. The roof is subject to downward pressure and, more importantly, to uplift. Often a roof is sucked up by the uplift drag of the wind. Usually the failure of houses is in the devices that tie the parts of the structure together. All structural members (beams, rafters, columns) should be fastened together

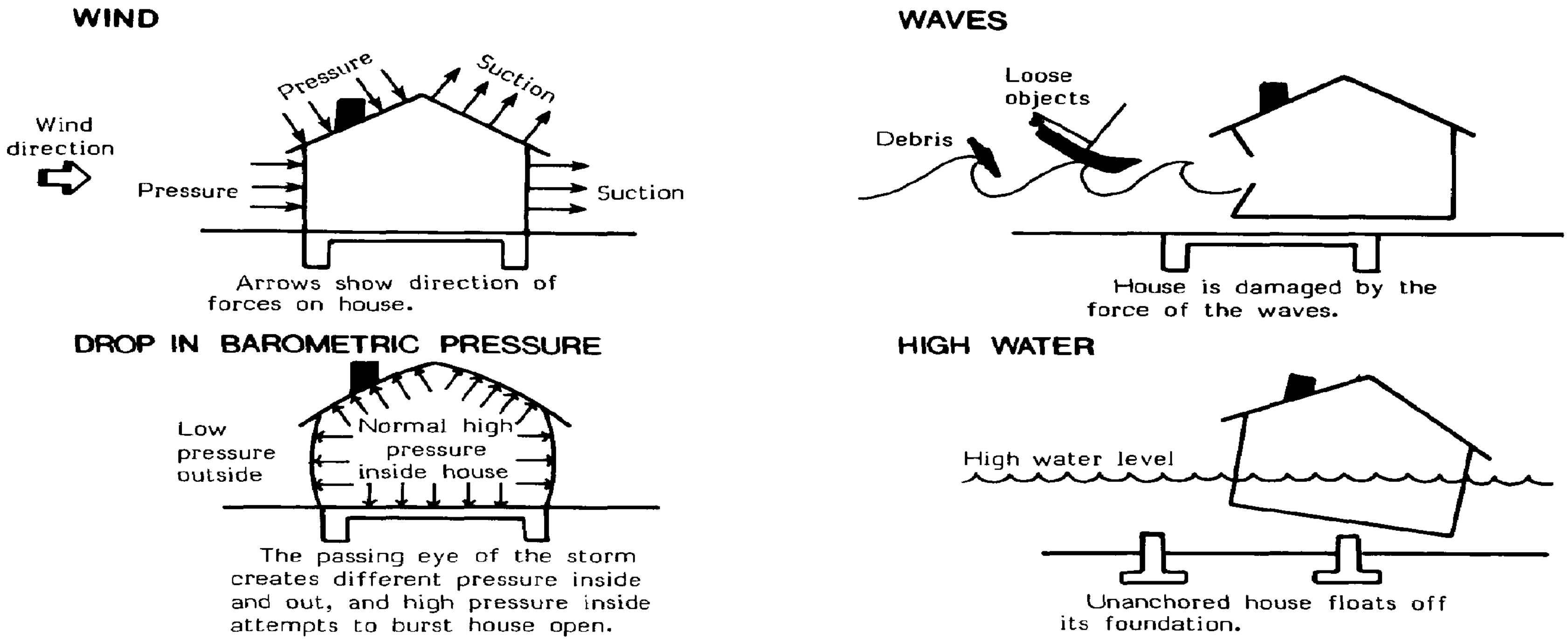


Fig. 6.1. Forces to be reckoned with at the shoreline.

on the assumption that about 25 percent of the vertical load on the member may be a force coming from any direction (sideways or upwards). When lumber is poorly connected, its capacity for strength is wasted. Such structural integrity also is important if it is likely that the building may be moved to avoid destruction by shoreline retreat.

Storm surge

Storm surge is a rise in sea level above the normal water level during a storm. During hurricanes the inundation of the coastal zone by storm surge and the accompanying storm waves causes most property damage and loss of life. (Storm surge was discussed in chapter 2.)

Often the pressure of the wind backs water into streams, estuaries, or bays already swollen from the exceptional rainfall brought on by the hurricane. Water is piled into the sounds between islands and the mainland by the offshore storm. This flooding is particularly dangerous when the wind pressure keeps the tide from running out of inlets, so that the next normal high tide pushes the accumulated waters back and higher still.

People who have cleaned the mud and contents out of a house subjected to flooding will retain vivid memories of the effects of that flooding. Flooding can cause an unanchored house to float off its foundation and come to rest against another house, severely damaging both. Even if the house itself is left structurally intact, flooding may destroy its contents.

Proper coastal development takes into account the expected level and frequency of storm surge for the area. In general, building standards require that the lowest floor of a dwelling be above the 100-year flood level. At this level a building has a 1 percent probability of being flooded in any given year.

Hurricane waves

Hurricane waves can cause severe damage not only in forcing water onshore to flood buildings but also in throwing boats, barges, piers, houses, and other floating debris inland against standing structures. In addition, waves can destroy coastal structures by scouring away the underlying sand, causing collapse. It is possible to design buildings for survival in crashing storm surf. Many lighthouses, for example, have survived storm surge. But in the balanced-risk equation, it usually is not economically feasible to build ordinary cottages to resist the more powerful of such forces. On the other hand, cottages can be made considerably more stormworthy by following the suggestions in the following sections.

The force of a wave may be realized when one considers that a cubic yard of water weighs over three-fourths of a ton; hence, a breaking wave moving shoreward at a speed of several tens of miles per hour is one of the most destructive elements of a hurricane.

Barometric pressure changes

Barometric pressure changes also may be minor contributors to structural failure. If a house is sealed at a normal barometric pressure of 30 inches of mercury, and the external pressure suddenly drops to 26.61 inches as happened in Hurricane Camille, the pressure exerted within the house would be 245 pounds per square foot. An ordinary house would explode if it were leakproof. In tornadoes, where there is a severe pressure differential, many houses do just that. In a hurricane the problem is much less severe. Fortunately, most houses leak; yet they must leak fast enough to prevent damage. Given the more destructive forces of hurricane wind and waves, pressure differential may be of minor concern. Venting the underside of the roof at the eaves is a common means of equalizing internal and external pressure.

Figure 6.2 illustrates some of the actions that a homeowner can take to deal with the forces just described.

House selection

Having listed the forces to which a house near the beach may be subjected, and having presented a guide for evaluating the site, let us turn to the house itself. Some types of houses are better than others, and an awareness of the differences will help you make a better selection either in building a new house or buying an existing place.

Worst of all are unreinforced masonry houses, whether they be brick, concrete block, hollow clay-tile, or brick veneer, as they cannot withstand the lateral forces of wind, wave, and settling of foundation.

Adequate and extraordinary reinforcing in coastal regions will alleviate the inherent weaknesses of unit masonry, if done properly. Reinforced concrete and steel frames are excellent but are rarely used in the construction of small residential structures.

It is hard to beat a wood frame house that is properly braced and anchored, and its members well connected. The well-built wood house will often hold together as a unit even if moved off its foundation, where other types of structure would disintegrate. Although all of the structural types noted above are to be found in the coastal zone, newer structures tend to be of the elevated wood frame type.

Keeping dry: pole or "stilt" houses

In coastal areas subject to flooding nearly all communities have adopted building codes or zoning ordinances that comply with minimum standards established by the National Flood Insurance Program. In V-zones these ordinances and/or codes generally require that residences be elevated on pilings or columns so that the lowest horizontal structural member of the lowest floor is at or above the 100-year flood elevation. Areas below that elevation must be left free of obstructions, or at least enclosed by walls that will break away if struck by waves, and contain no habitable space. The 100-year flood elevation is being adjusted upward in these communities to include wave heights that are superimposed on top of the storm surge.

In A-zones residences can be elevated by any means so that the lowest floor is at or above the elevation of the 100-year flood. Although elevation of a residence by building a mound out of fill generally would be permitted in A-zones, this method is *not* ad-

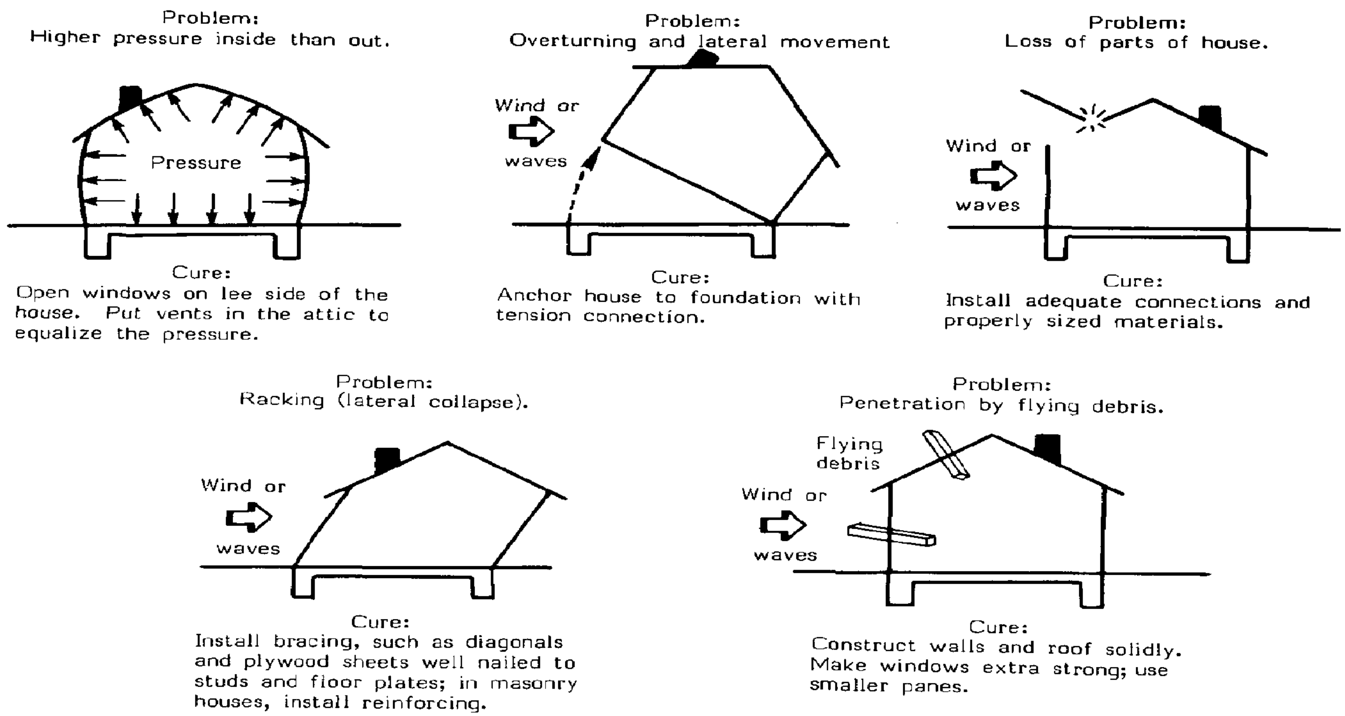


Fig. 6.2. Modes of failure and how to deal with them. Modified from U.S. Civil Defense Preparedness Agency Publication TR83.

visable in most coastal areas because the fill is likely to be eroded by waves or flowing floodwaters. Because of these hazards, modern flood-prone structures are elevated on pilings that are well anchored in the subsoil.

Current building design criteria for pole-house construction under the flood insurance program are outlined in the *Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas* (reference 108, appendix C). Regardless of these requirements, pole-type construction with deep embedment of piles is advisable in any area where waves and storm-surge floodwaters will erode foundation material.

Materials used in pole construction include the following:

Piles. Piles are long, slender columns of wood, steel, or concrete driven into the earth to a sufficient depth to support the vertical load of the house and to withstand the horizontal forces of flowing water, wind, and water-borne debris. Pile construction is especially suitable in areas where scouring (soil "washing out" from under the foundation of a house) is a problem.

Posts. Posts are usually of wood; if of steel, they are called *columns*. Unlike piles, they are not driven into the ground but, rather, are placed in a pre-dug hole at the bottom of which may be a concrete pad (fig. 6.3). Posts may be held in place by backfilling and tamping earth or by pouring concrete into the hole after the pole is in place. Posts are more readily aligned than driven piles and are, therefore, better to use if poles must extend to the roof. In general, treated wood is the cheapest and most common material for both posts and piles.

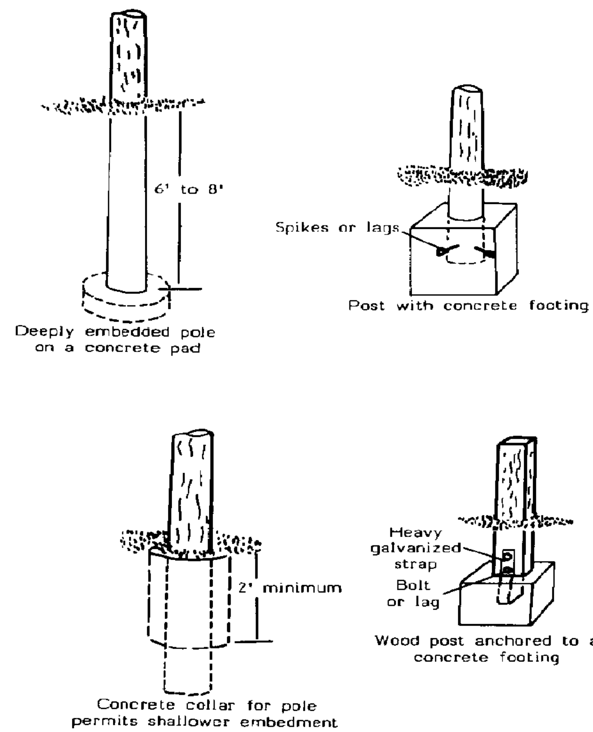


Fig. 6.3. Shallow and deep supports for poles and posts. Source: Southern Pine Association.

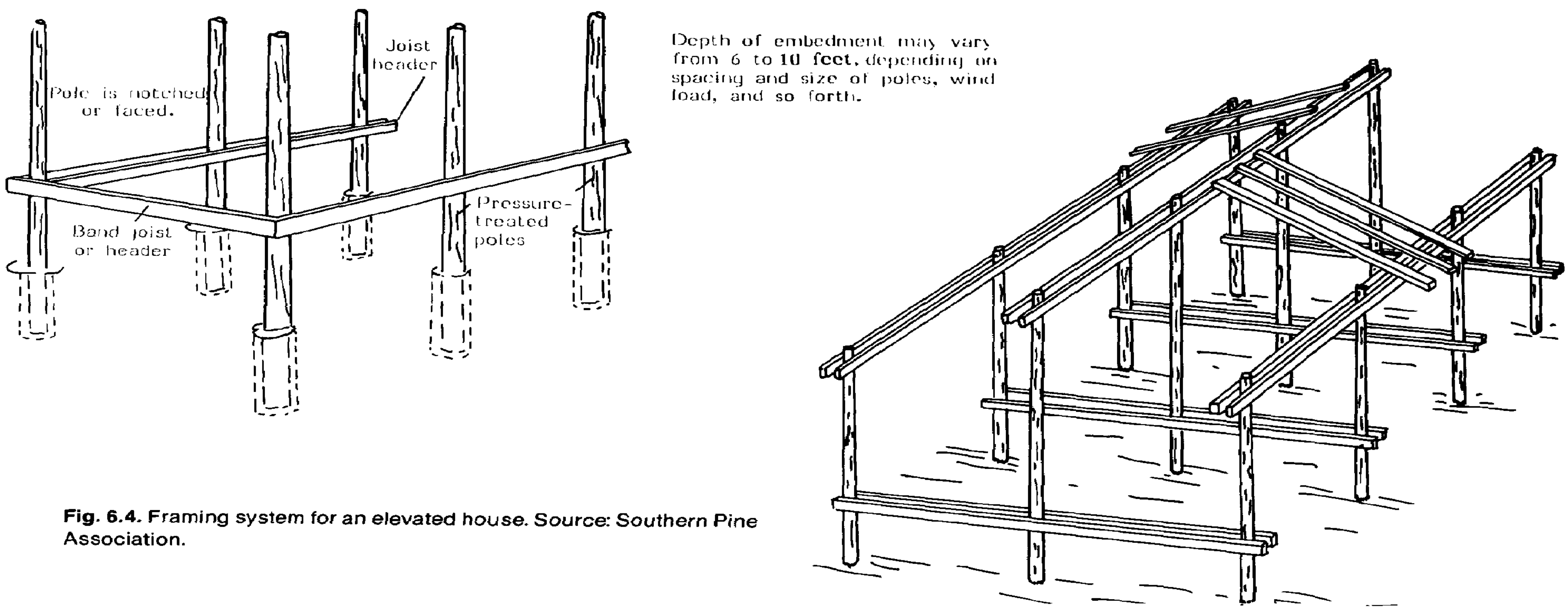


Fig. 6.4. Framing system for an elevated house. *Source: Southern Pine Association.*

Piers. Piers are vertical supports, thicker than piles or posts, usually made of reinforced concrete or reinforced masonry (concrete blocks or bricks). They are set on footings and extend to the underside of the floor frame.

Pole construction can be of two types. The poles can be cut off at the first floor level to support the platform that serves as the dwelling floor. In this case, piles, posts, or piers can be used. Or they can be extended to the roof and rigidly tied into both the floor and the roof. In this way they become major framing members for the structure and provide better anchorage to the house as a whole (figs. 6.4 and 6.5). A combination of full- and floor-height poles is used in some cases, with the shorter poles restricted to supporting the floor inside the house (fig. 6.6).

Where the foundation material can be eroded by waves or winds, the poles should be deeply embedded and solidly anchored either by driving piles or by drilling deep holes for posts and putting in a concrete pad at the bottom of each pole. Where the embedment is shallow, a concrete collar around the poles improves anchorage (fig. 6.3). The choice depends on the soil conditions. Piles are more difficult than posts to align to match the house frame; posts can be positioned in the holes before backfilling. Inadequate piling depths, improper piling-to-floor connections, and inadequate pile bracing all contribute to structural failure when storm waves liquify and erode sand support (fig. 6.7).

When post holes are dug, rather than pilings driven, the posts should extend 4 to 8 feet into the ground depending on the type of soil and the weight (vertical load) on the pole. Hole excavations

Fig. 6.5. Pole house with poles extending to the roof. Extending poles to the roof, instead of the usual method of cutting them off at the first floor, greatly strengthens a beach cottage. Photo by Orrin Pilkey, Jr.

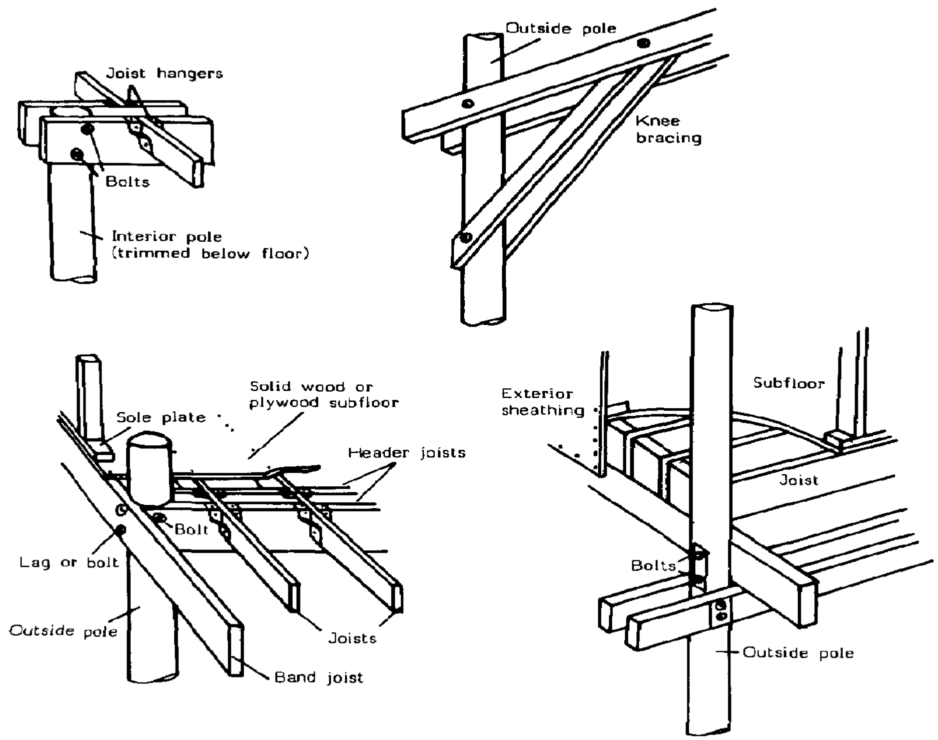


Fig. 6.6. Tying floors to poles. Source: Southern Pine Association.

beyond 8 feet become excessively expensive. For this reason, posts do not provide suitable deep anchorage in V-zones or where deep soil erosion is likely to occur. Post foundations are suitable for some parts of the A-zone. The lower end of the post should rest on a concrete pad, spreading the load to the soil over a greater area to prevent settlement. When the soil permits the embedment to be shallow, it is best to tie the post down to the footing with straps or other anchoring devices.

The depth of embedment of driven or jetted piles depends upon the type of soil, the location of the house with respect to the sea, and other criteria. Loose sand requires more penetration than dense sand and still more than dense clay. The minimum penetration should be 8 feet, but a much greater penetration can be dictated by local building codes. As an example of a special situation, FEMA recommends that piles in the V-zone penetrate sand to at least a tip elevation of 5 feet below mean sea level if the Base Flood Elevation is 10 feet or less above mean sea level. If the house must be elevated higher than 10 feet above mean sea level (expected height of water plus waves), then the pile tips should penetrate at least to 10 feet below mean sea level. You may want posts or pilings to extend deeper than *minimum* code requirements.

The floor and the roof should be securely connected to the poles with bolts or other fasteners. When the floor rests on poles that do not extend to the roof, attachment is even more critical. A system of metal straps is often used. Unfortunately, it is very common for builders simply to attach the floor joists or beams to a notched pole by 1 or 2 undersized bolts. Hurricanes have proven this method

Fig. 6.7. Inadequate piling depths, and inadequate size and bracing of pilings are common causes of failure during storm-surge flooding as resulted from Hurricane Frederic. About 4 to 6 feet of sand was scoured from the base of these pilings, and the remaining sand may have been liquefied to a depth of 3 to 4 feet by the floodwaters. Hence, the leaning pilings. Damage to the superstructure was caused mainly by wind. Photo by H. C. Miller.

insufficient. During the next hurricane on the northeast Gulf Coast many houses will be destroyed because of inadequate attachment.

Local building codes specify the size, quality, and spacing of the piles, ties, and bracing, as well as the methods and materials for fastening the structure to them. Building codes often are minimal requirements; however, building inspectors are usually amenable to allowing designs that are equal or more effective.

The space under an elevated house, whether pole-type or otherwise, must be kept free of obstructions to minimize the impact of waves and floating debris. The convenience of closing in the ground floor for a garage or extra bedroom may be costly because it violates insurance requirements and actually can cause the loss of the house in a hurricane.

In some instances it may be desirable to enclose part or all of the space under the elevated structure. If this is done, the walls should be built so they will break away under pressure from water or debris, but in such a manner that they will not float away and add to the water-borne debris problem. This can be done in several ways, including hinging so they will swing out of the way, or making them detachable for removal prior to the storm. The National Flood Insurance Program suggests open-wood latticework as the preferred option for people who want enclosed space for aesthetic reasons. Generally, enclosing the space is discouraged.

An existing house: what to look for, where to improve

If instead of building a new house, you are selecting a house already built in an area subject to flooding and high winds, consider the following factors: (1) where the house is located, (2) how well the house is built, and (3) how the house can be improved.

Geographic location

Evaluate the site of an existing house using the same principles given earlier for the evaluation of a possible site for new construction. House elevation, frequency of high water, escape route, and how well the lot drains should be emphasized, but you should go through the complete site safety checklist in chapter 4.

You can modify the house after you have purchased it, but you cannot prevent hurricanes or winter storms. The first step is to stop and consider: do the pleasures and benefits of this location balance the risks and disadvantages? If not, look elsewhere for a home; if so, then evaluate the house itself.

How well built is the house?

In general, the principles used to evaluate an existing house are the same as those used in building a new one (references 107 to 125, appendix C). It should be remembered that many of the houses were built prior to the enactment of the National Flood Insurance Program and may not meet the standards required of structures or improvements built since then.

Before you thoroughly inspect the house in which you are interested, look closely at the adjacent homes. If poorly built, they may float over against your house and damage it in a flood. You may even want to consider the type of people you will have as neighbors. Will they "clear the decks" in preparation for a storm or will they leave items in the yard to become wind-borne missiles? The house itself should be inspected for the following:

The house should be well anchored to the ground. If it is simply resting on blocks, rising water may cause it to float off its foundation and come to rest against your neighbor's house or out in the middle of the street. If well built and well braced internally, it may be possible to move the house back to its proper location, but chances are great that the house will be too damaged to be habitable.

If the house is on piles, posts, or poles, check to see if the floor beams are adequately bolted to them. If it rests on piers, crawl under the house if space permits to see if the floor beams are securely connected to the foundation. If the floor system rests unanchored on piers, do not buy the house.

It is difficult to discern whether a house built on a concrete slab is properly bolted to the slab because the inside and outside walls hide the bolts. If you can locate the builder, ask if such bolting was done. Better yet, if you can get assurance that construction of the house complied with the provisions of a building code serving the needs of that particular region, you can be reasonably sure that all parts of the house are well anchored—the foundation to the ground, the floor to the foundation, the walls to the floor, and the roof to the walls (figs. 6.8, 6.9, and 6.10).

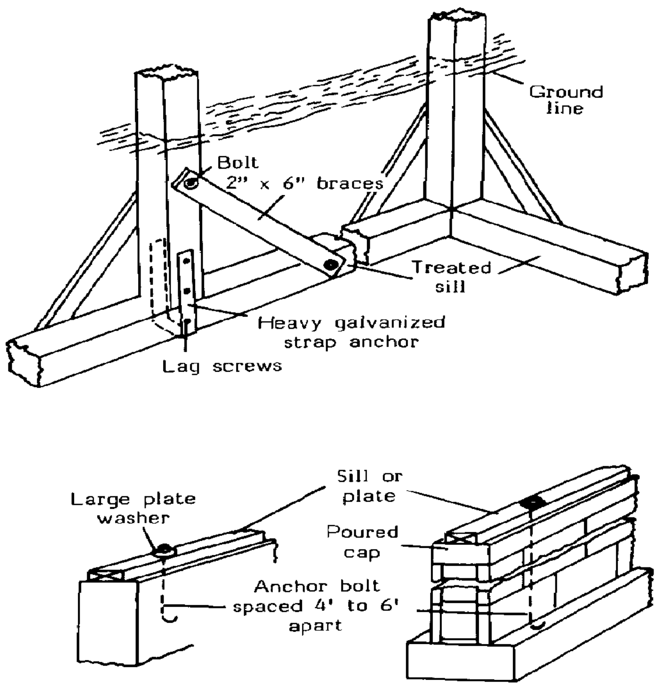


Fig. 6.8. Foundation anchorage. Top: anchored sill for shallow embedment. Bottom: anchoring sill or plate to foundation. Source of bottom drawing: *Houses Can Resist Hurricanes*, U.S. Forest Service Research Paper FPL 33.

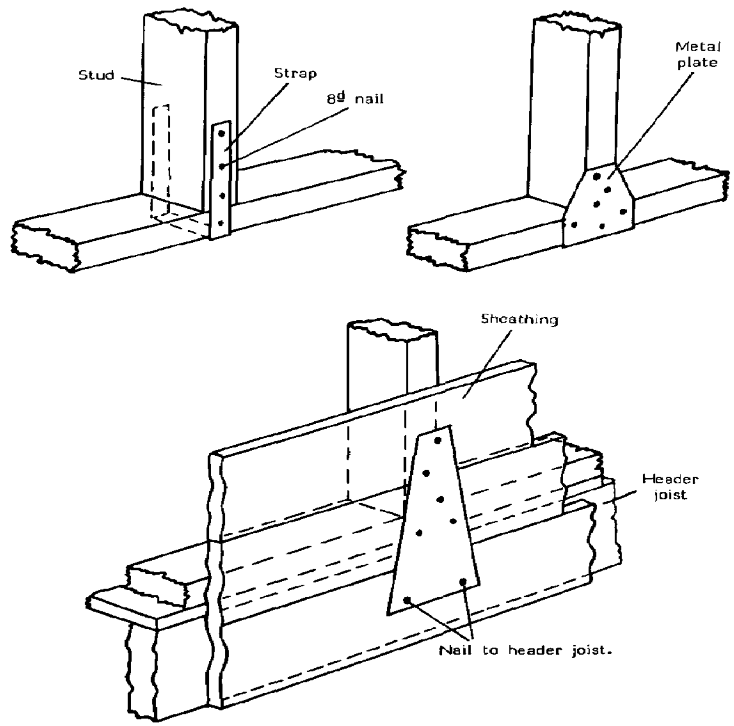


Fig. 6.9. Stud-to-floor, plate-to-floor framing methods. Source: *Houses Can Resist Hurricanes*, U.S. Forest Service Research Paper FPL 33.

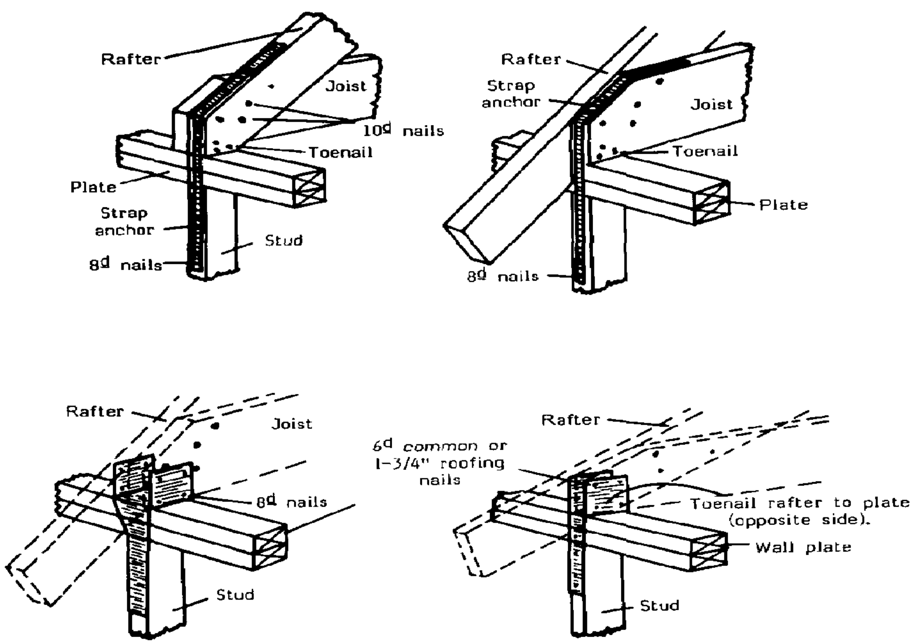


Fig. 6.10. Roof-to-wall connectors. The top drawings show metal strap connectors: left, rafter to stud; right, joist to stud. The bottom left drawing shows a double-member metal-plate connector—in this case with the joist to the right of the rafter. The bottom right drawing shows a single-member metal-plate connector. Source: *Houses Can Resist Hurricanes*, U.S. Forest Service Research Paper FPL 33.

Be aware that many builders, carpenters, and building inspectors who are accustomed to traditional construction are apt to regard metal connectors, collar beams, and other such devices as newfangled and unnecessary. If consulted, they may assure you that a house is as solid as a rock, when in fact it is far from it. Nevertheless, it is wise to consult the builder or knowledgeable neighbors when possible.

The roof should be well anchored to the walls. This will prevent uplifting and separation from the walls. Visit the attic to see if such anchoring exists. Simple toe-nailing (nailing at an angle) is not adequate; metal fasteners are needed. Depending on the type of construction and the amount of insulation laid on the floor of the attic, these may or may not be easy to see. If roof trusses or braced rafters were used, it should be easy to see whether the various members, such as the diagonals, are well fastened together. Again, simple toe-nailing will not suffice. Some builders, unfortunately, nail parts of a roof truss just enough to hold it together to get it in place. A collar beam or gusset at the peak of the roof (fig. 6.11) provides some assurance of good construction.

Quality roofing material should be well anchored to the sheathing. A poor roof covering will be destroyed by hurricane-force winds, allowing rain to enter the house and damage ceilings, walls, and the contents of the house. Galvanized nails (2 per shingle) should be used to connect wood shingles and shakes to wood sheathing and should be long enough to penetrate through the sheathing (fig. 6.11). Threaded nails should be used for plywood sheathing. For roof slopes that rise 1 foot for every 3 feet or more of hori-

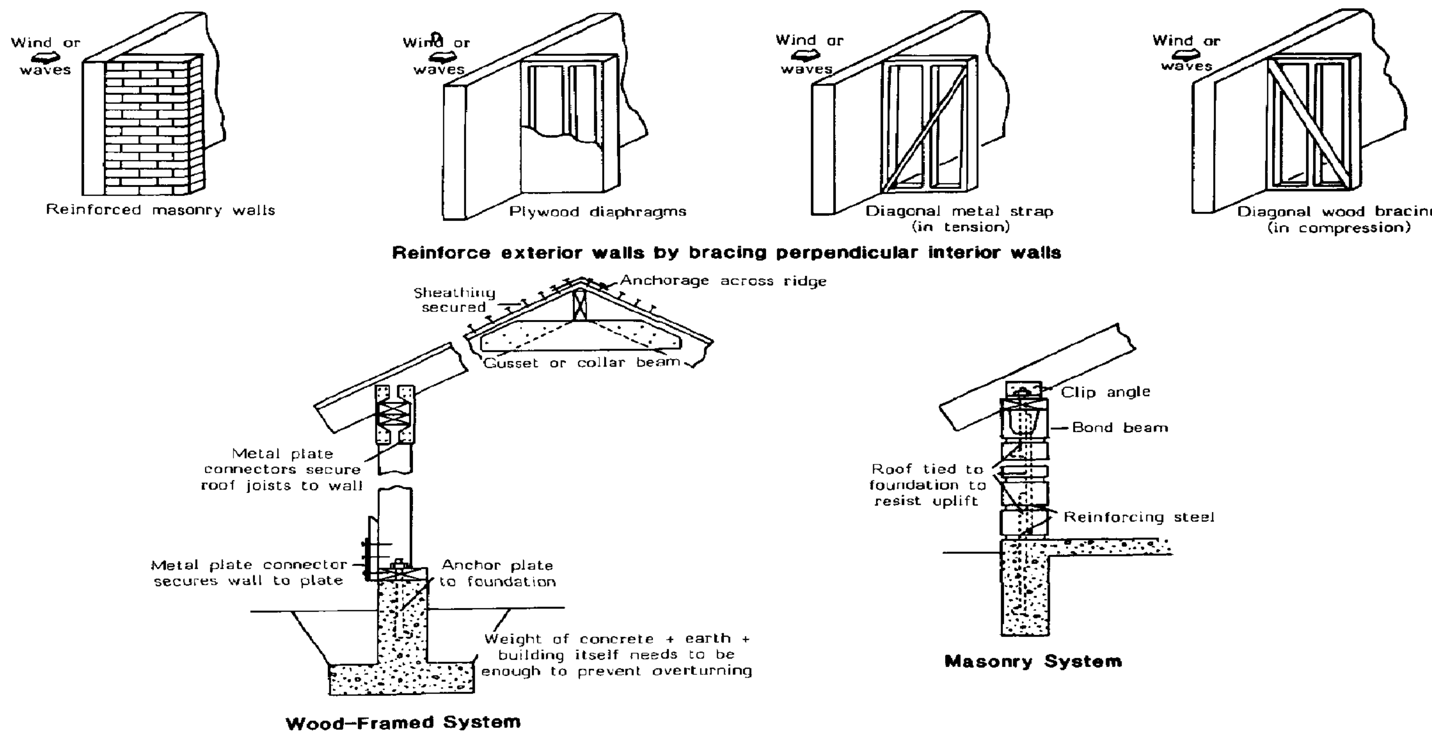


Fig. 6.11. Where to strengthen a house. Modified from: U.S. Civil Defense Preparedness Agency Publication TR83.

zontal distance, exposure of the shingle should be about one-fourth of its length (4 inches for a 16-inch single). If shakes (thicker and longer than shingles) are used, less than one-third of their length should be exposed.

In hurricane areas asphalt shingles should be exposed somewhat less than usual. A mastic or seal-tab type or an interlocking shingle of heavy grade should be used. A roof underlay of asphalt-saturated felt and galvanized roofing nails or approved staples (6 for each 3-tap strip) should be used.

The fundamental rule to remember in framing is that all structural elements should be fastened together and anchored to the ground in such a manner as to resist all forces, regardless of which direction these forces may come from. This prevents overturning, floating off, racking, or disintegration.

The shape of the house is important. A hip roof, which slopes in 4 directions, is better able to resist high winds than a gable roof, which slopes in 2 directions. This was found to be true in Hurricane Camille (1969) in Mississippi and later in Cyclone Tracy, which devastated Darwin, Australia, in December 1974. The reason is twofold: the hip roof offers a smaller shape for the wind to blow against, and its structure is such that it is better braced in all directions.

Note also the horizontal cross section of the house (the shape of the house as viewed from above). The pressure exerted by a wind on a round or elliptical shape is about 60 percent of that exerted on the common square or rectangular shape; the pressure exerted on a hexagonal or octagonal cross section is about 80 percent of that exerted on a square or rectangular cross section.

The design of a house or building in a coastal area should minimize structural discontinuities and irregularities. A house should have a minimum of nooks and crannies and offsets on the exterior because damage to a structure tends to concentrate at these points. Some of the newer beach cottages along the Gulf Coast are of a highly angular design with such nooks and crannies. Award-winning architecture will be a storm loser if the design has not incorporated the technology for maximizing structural integrity with respect to storm forces. When irregularities are absent, the house reacts to storm winds as a complete unit.

Brick, concrete-block, and masonry-wall houses should be adequately reinforced. This reinforcement is hidden from view. Building codes applicable to high-wind areas often specify the type of mortar, reinforcing, and anchoring to be used in construction. If you can get assurance that the house was built in compliance with a building code designed for such an area, consider buying it. At all costs avoid unreinforced masonry houses.

A poured concrete bond-beam at the top of the wall just under the roof is 1 indication that the house is well built (fig. 6.12). Most bond beams are formed by putting in reinforcing and pouring concrete in U-shaped concrete blocks. From the outside, however, you cannot distinguish these U-shaped blocks from ordinary ones and therefore cannot be certain that a bond beam exists. The vertical reinforcing should penetrate the bond beam.

Some architects and builders use a stacked bond (1 block directly above another), rather than overlapped or staggered blocks, because they believe it looks better. The stacked bond is definitely

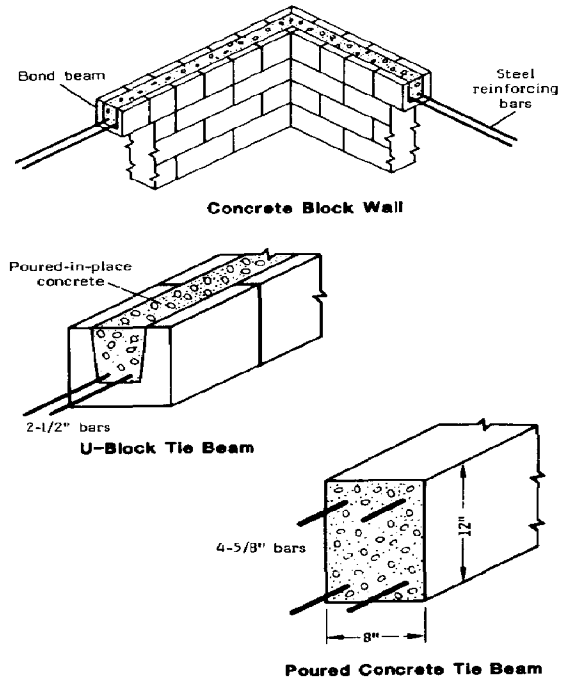


Fig. 6.12. Reinforced tie beam (bond beam) for concrete block walls—to be used at each floor level around the perimeter of the exterior walls.

weaker than the latter. Unless you have proof that the walls are adequately reinforced to overcome this lack of strength, you should avoid this type of construction.

In past hurricanes the brick veneer of many houses has separated from the wood frame, even when the houses remained standing. Asbestos-type outer wall panels used on many houses in Darwin, Australia, were found to be brittle and broke up under the impact of wind-borne debris in Cyclone Tracy. Both types of construction should be avoided along the coast.

Ocean-facing glazing (windows, glass doors, glass panels) should be minimal. Although large open glass areas facing the ocean provide an excellent sea view, such glazing may present several problems. The obvious hazard is glass that disintegrates and blows inward during a storm. Glass projectiles are lethal. Less frequently recognized problems include the fact that glass may not provide as much structural strength as wood, metal, or other building materials; and ocean-facing glass is commonly damaged through sediment sand blasting, transported by normal coastal winds. The solution to this latter problem may be in reducing the amount of glass in the original design, or installing storm shutters that come in a variety of materials from steel to wood.

Consult a good architect or structural engineer for advice if you are in doubt about any aspects of the house. A few dollars spent for wise counsel may save you from later financial grief.

To summarize, the beach house should have: (1) roof tied to walls, walls tied to foundation, and foundation anchored to the earth (the connections potentially are the weakest link in the

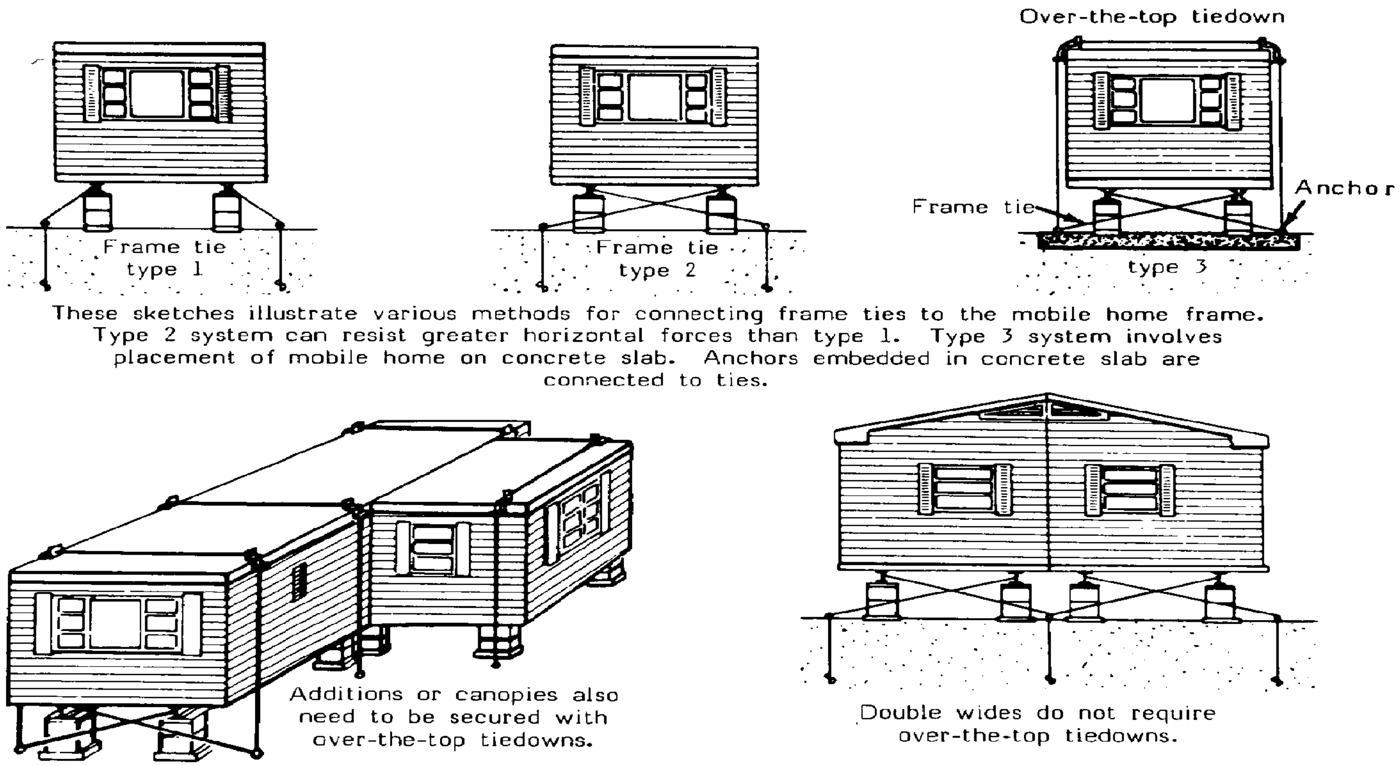


Fig. 6.13. Tiedowns for mobile homes. Source: U.S. Civil Defense Preparedness Agency Publication TR75.

structural system); (2) a shape that resists storm forces; (3) floors high enough (sufficient elevation) to be above most storm waters (usually the 100-year flood level plus 2 to 6 feet); (4) piles that are of sufficient depth or embedded in concrete to anchor the structure and to withstand erosion; and (5) pilings that are well braced.

What can be done to improve an existing house?

If you presently own a house or are contemplating buying one in a hurricane-prone area, you will want to know how to improve occupant protection in the house. If so, you should obtain the excellent publication, *Wind Resistant Design Concepts for Residences* (TR83), by Delbart B. Ward (reference 111, appendix C). Of particular interest are the sections on building a refuge shelter module within a residence. Whereas TR83 is aimed at residences, supplements TR83A and B (reference 112, appendix C) deal with larger buildings and may be of interest to the general public, especially residents in urban areas. These references provide a means of checking on whether the responsible authorities are doing their jobs to protect schools, office buildings, and apartments. A number of other pertinent references are listed in appendix C.

Suppose your house is resting on blocks, but not fastened to them, and thus is not adequately anchored to the ground. Can anything be done? One solution is to treat the house like a mobile home by screwing ground anchors into the ground to a depth of 4 feet or more and fastening them to the underside of the floor systems. See figures 6.13 and 6.14 for illustrations of how ground anchors can be used.

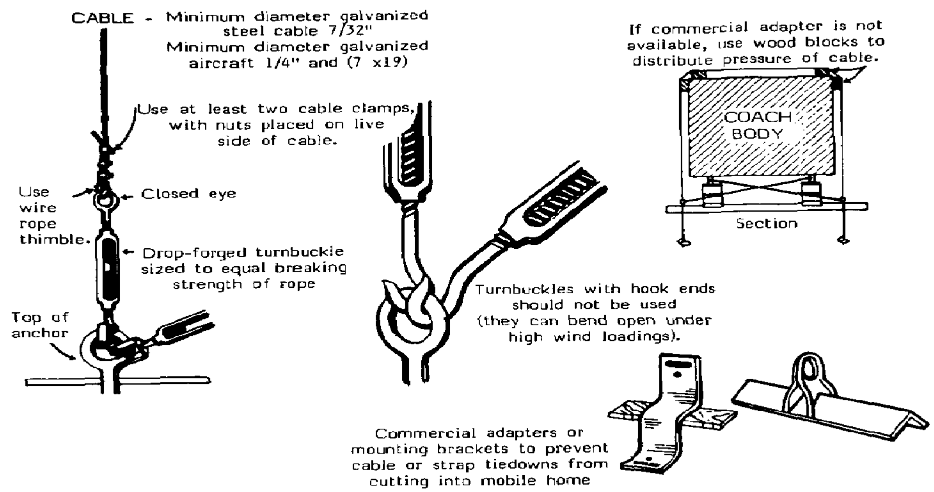


Fig. 6.14. Hardware for mobile home tiedowns. Modified from U.S. Civil Defense Preparedness Agency Publication TR75.

Calculations to determine the needed number of ground anchors will differ between a house and a mobile home because each is affected differently by the forces of wind and water. Note that recent practice is to put these commercial steel-rod anchors in at an angle in order to better align them with the direction of the pull. If a vertical anchor is used, the top 18 inches or so should be encased in a concrete cylinder about 12 inches in diameter. This prevents the top of the anchor rod from bending or slicing through the wet soil from the horizontal component of the pull.

Diagonal struts, either timber or pipe, also may be used to anchor a house that rests on blocks. This is done by fastening the upper ends of the struts to the floor system and the lower ends to individual concrete footings substantially below the surface of the ground. These struts must be able to take both uplift (tension) and compression and should be tied into the concrete footing with anchoring devices such as straps or spikes.

If the house has a porch with exposed columns or posts, it should be possible to install tiedown anchors on their tops and bottoms. Steel straps should suffice in most cases.

When accessible, roof rafters and trusses should be anchored to the wall system. Usually the roof trusses or braced rafters are sufficiently exposed to make it possible to strengthen joints (where 2 or more members meet) with collar beams or gussets, particularly at the peak of the roof (figs. 6.10 and 6.11).

A competent carpenter, architect, or structural engineer can review the house with you and help you decide what modifications are most practical and effective. Do not be misled by someone who is resistant to new ideas. One builder told a homeowner, "You don't want all those newfangled straps and anchoring devices. If you use them, the whole house will blow away, but if you build in the usual manner [with members lightly connected], you may lose only part of it."

In fact, the very purpose of the straps is to prevent any or all of the house from blowing away. The Standard Building Code for hurricane-prone areas says, "Lateral support securely anchored to all walls provides the best and only sound structural stability against horizontal thrusts, such as winds of exceptional velocity" (reference 113, appendix C). And the cost of connecting all elements securely adds very little to the cost of the frame of the dwelling, usually under 10 percent, and a very much smaller percentage to the total cost of the house.

If the house has an overhanging eave and there are no openings on its underside, it may be feasible to cut openings and screen them. These openings keep the attic cooler (a plus in the summer) and help to equalize the pressure inside and outside of the house during a storm with a low-pressure center.

Another way to improve a house is to modify a special room so that it can be used as an emergency refuge in case you are trapped in a major storm. This is *not* an alternative to evacuation prior to a hurricane. Examine the house and select the best room to stay in during a storm. A small windowless room such as a bathroom, utility room, den, or storage space is usually stronger than a room with windows. A sturdy inner room, with more than 1 wall between it and the outside, is safest. The fewer doors, the better; an adjoining wall or baffle wall shielding the door adds to the protection.

Consider bracing or strengthening the interior walls. Such reinforcement may require removing the surface covering and installing plywood sheathing or strap bracing. Where wall studs are exposed, bracing straps offer a simple way to achieve needed reinforcement against the wind. These straps are commercially produced and are made of 16-gauge galvanized metal with prepunched holes for nailing. These should be secured to studs and wall plates as nail holes permit (fig. 6.11). Bear in mind that they are good only for tension.

If, after reading this, you agree that something should be done to your house, do it now. Do not put it off until the next hurricane or big storm hits you!

Mobile homes: limiting their mobility

Because of their light weight and flat sides, mobile homes are vulnerable to the high winds of hurricanes, tornadoes, and severe storms. Such winds can overturn unanchored mobile homes or smash them into neighboring homes and property. Nearly 6 million Americans live in mobile homes today, and the number is growing. Twenty or 30 percent of single-family housing production in the United States consists of mobile homes. High winds damage or destroy nearly 5,000 of these homes every year, and the number will surely rise unless protective measures are taken. As one man whose mobile home was overturned in Hurricane Frederic (1979) so aptly put it: "People who live in flimsy houses shouldn't have hurricanes."

Several lessons can be learned from past experiences in storms. First, mobile homes should be located properly. After Hurricane Camille (1969) it was observed that where mobile home parks were surrounded by woods and where the units were close together, damage was minimized, caused mainly by falling trees. In unprotected areas, however, many mobile homes were overturned and often destroyed by the force of the wind. The protection afforded by trees is greater than the possible damage from falling limbs. Two or more rows of trees are better than a single row, and trees 30 feet or more in height give better protection than shorter ones. If possible, position the mobile home so that the narrow side faces the prevailing winds.

Locating a mobile home in a hilltop park will greatly increase its vulnerability to the wind. A lower site screened by trees is safer from the wind, but it should be above storm-surge flood levels. A location that is too low, obviously, increases the likelihood of flooding. There are fewer safe locations for mobile homes than for stilt houses.

A second lesson taught by past experience is that the mobile home must be tied down or anchored to the ground so that it will not overturn in high winds (figs. 6.13, 6.14, and table 6.1). Simple prudence dictates the use of tiedowns, and in many communities ordinances require it. Many insurance companies, moreover, will not insure mobile homes unless they are adequately anchored with tiedowns.

Table 6.1. Tiedown anchorage requirements

Wind velocity (mph)	10- and 12-ft.-wide mobile homes: 30 to 50 ft. long		10- and 12-ft.-wide mobile homes: 50 to 60 ft. long		12- and 14-ft.-wide mobile homes, 60 to 70 ft. long	
	No. of frame ties	No. of over-the-top ties	No. of frame ties	No. of over-the-top ties	No. of frame ties	No. of over-the-top ties
70	3	2	4	2	4	2
80	4	3	5	3	5	3
90	5	4	6	4	7	4
100	6	5	7	5	8	6
110	7	6	9	6	10	7

A mobile home may be tied down with cable or rope, or rigidly attached to the ground by connecting it to or within a wood-post foundation system. An alert owner of a mobile home park can provide permanent concrete anchors or piers to which hold-down ties may be fastened. In general, an entire tiedown system costs only a nominal amount.

A mobile home should be properly anchored with both ties to the frame and over-the-top straps; otherwise it may be damaged by sliding, overturning, or tossing. The most common cause of major damage is the tearing away of most or all of the roof. When this happens the walls are no longer adequately supported at the top and are more prone to collapse (fig. 6.15). Total destruction of a mobile home is more likely if the roof blows off, especially if the roof blows off first and then the home overturns. The necessity for anchoring cannot be overemphasized. There should be over-the-top tiedowns to resist overturning and frame ties to resist sliding off the piers. This applies to single mobile homes up to 14 feet in width. Double wides do not require over-the-top ties, but they do require frame ties.

Mobile home owners should be sure to obtain a copy of the booklet *Protecting Mobile Homes from High Winds* (reference 115, appendix C), which treats the subject in more detail. The booklet lists specific steps that one should take on receiving a hurricane warning and suggests a type of mobile home park community shelter. It also includes a map of the United States that indicates areas subject to the strongest sustained winds.

High-rise buildings: the urban shore

A high-rise building on the beach is generally designed by an architect and a structural engineer who are presumably well qualified and aware of the requirements for building on the shoreline.

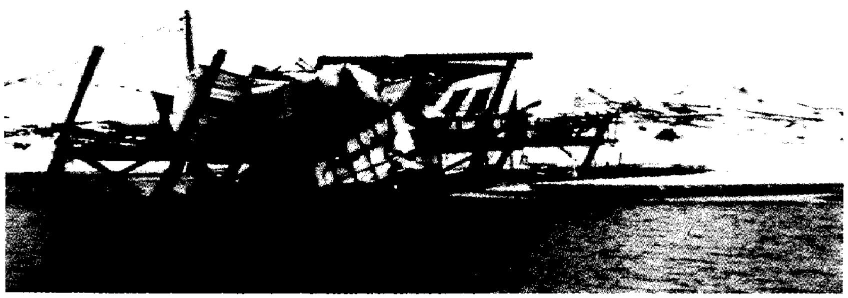


Fig. 6.15. Mobile home in wooden frame was destroyed by Hurricane Frederic, but it was held in place and did not become a battering ram. Photo by H. C. Miller.

Tenants of such a building, however, should not assume that it is invulnerable. People living in apartment buildings of 2 or 3 stories were killed when the buildings were destroyed by Hurricane Camille in Mississippi in 1969. Storms have torn away the fronts of 5-story buildings in Delaware. Larger high-rises have yet to be thoroughly tested by a major hurricane.

The first aspect of high-rise construction that a prospective apartment dweller or condo owner must consider is the type of pilings used. High-rises near the beach should be built so that even if the foundation is severely undercut during a storm, the building will remain standing. It is well known in construction circles that shortcuts are sometimes taken by less scrupulous builders, and pilings are not driven deeply enough. Just as important as driving the pilings deep enough to resist scouring and to support the loads they must carry is the need to fasten them securely to the structure above them that they support. The connections must resist horizontal loads from winds and waves during a storm and also uplift from the same sources. It is a joint responsibility of builders and building inspectors to make sure the job is done right. Hurricane Eloise (1975) exposed the foundation of a just-under-construction high-rise in Florida, revealing that some of the pilings were not attached to the building. This happened in Panama City Beach, but such problems probably exist everywhere that high-rises crowd the beach.

Despite the assurances that come with an engineered structure, life in a high-rise building holds definite drawbacks that prospective tenants should take into consideration. The negative conditions that must be evaluated stem from high wind, high water, and poor foundations.

Pressure from the wind is greater near the shore than it is inland, and it increases with height. If you are living inland in a 2-story house and plan to move to the eleventh floor of a high-rise on the shore, you should expect 5 times more wind pressure than you are accustomed to. This can be a great and possibly devastating surprise.

The high wind pressure actually can cause unpleasant motion of the building. It is worthwhile to check with current residents of a high-rise to find out if it has undesirable motion characteristics; some have claimed that the swaying is great enough to cause motion sickness. More seriously, high winds can break windows, damage property, and injure people. Tenants of severely damaged buildings will have to relocate until repairs are made.

Those who are interested in researching the subject further—even the knowledgeable engineer or architect who is engaged to design a structure near the shore—should obtain a copy of *Structural Failures: Modes, Causes, Responsibilities* (reference 116, appendix C). Of particular importance is the chapter entitled, "Failure of Structures Due to Extreme Winds." This chapter analyzes wind damage to engineered high-rise buildings from the storms at Lubbock and Corpus Christi, Texas, in 1970.

Another occurrence that affects a multistoried building more seriously than a low-occupancy structure is a power failure or blackout. Such an occurrence is more likely along the coast than inland because of the more severe weather conditions associated with coastal storms. A power failure can cause great distress. People can be caught between floors in an elevator. New York City had that experience once on a large scale. Think of the mental and physical distress after several hours of confinement. And compound this with the roaring winds of a hurricane whipping around the building, sounding like a freight train. In this age of electricity it is easy to imagine many of the inconveniences that can be caused by a power failure in a multistory building.

Fire is an extra hazard in a high-rise building. Even recently constructed buildings seem to have difficulties. The television pictures of a woman leaping from the window of a burning building in New Orleans rather than be incinerated in the blaze are a horrible reminder from recent history. The number of hotel fires of the past few years further demonstrates the problem. Fire Department equipment reaches only so high. And many areas along the coast are too sparsely populated to afford that particular type of high-reaching equipment.

Fire and smoke travel along ventilation ducts, elevator shafts, corridors, and similar passages. The situation *can be* corrected and the building made safer, especially if it is new. Sprinkler systems should be operated by gravity water systems rather than by powered pumps (because of possible power failure), i.e., from water tanks higher up in the building. Battery-operated emergency lights that come on only when the other lights fail, better fire walls and automatic sealing doors, pressurized stairwells, and emergency elevators in pressurized shafts will contribute to greater safety. Unfortunately, all of these improvements cost money, and that is why they are often omitted unless required by the building code.

There are 2 interesting reports on damage caused by Hurricane Eloise, which struck the Florida Panhandle the morning of September 23, 1975. One is by Herbert S. Saffir, a Florida consulting engineer; the other is by Bryon Spangler of the University of Florida. The forward movement of the hurricane was unusually fast, causing its duration in a specific area to be lessened, thus minimizing damage from both wind and tidal surge. The stillwater height at Panama City was 16 feet above mean sea level, plus about a 3-foot topping wave; wind gusts of 154 mph for a period of one-half hour were measured.

At least one-third of the older structures in the Panama City Beach area collapsed. These were the beach-front motels, restaurants, apartments and condominium complexes, and some permanent residences. The structures built on pilings survived with minimal damage. In one case, part of a motel was on spread footings and part on piles. Only the part on spread footings was severely damaged.

The anchorage systems, connections between concrete piles or concrete piers, and the grade beams under several high-rise buildings were inadequate to resist uplift loads, illustrating that code enforcement and proper inspection by a qualified professional is essential.

Many of the residences and some of the buildings were built on spread footings that failed because the sand they were resting on washed away with scour. Failure of the footings resulted in failure of the superstructure. Some of the high-rise buildings suffered glass damage in both windows and sliding glass doors.

Apparently few, if any, of the residences and buildings were built to conform to the Southern Standard Building Code requirements because much of the construction preceded the use of the code, so it was not legally applicable. If such requirements had been met, much of the damage could have been prevented at a minimum of cost.

Some surprising things were noticed. In almost every case where there was a swimming pool, considerable erosion occurred. Loss of sand beneath the walkways prior to the storm created a channel for the water to flow through and wash out more sand during the storm, which in turn increased both the velocity and quantity of the flow of water in the channel. This flow ate away the sand supporting adjacent structures, accelerating their failure.

Slabs on grade (on the ground) performed poorly. Often wave action washed out the sand underneath the slab. When this occurred there was no longer support for the structure above it, and failure resulted.

The storm revealed some shoddy construction. Some builders had placed wire mesh for a slab directly on the sand. Then the concrete was poured on top of it, leaving the mesh below and in the sand where it served no structural purpose. To be effective, the mesh should have been set on blocks or chairs, or pulled up into the slab during the pouring of the concrete.

In some cases cantilevered slabs for overhangs were reinforced for the usual downward gravity loads. Unfortunately when waves dashed against the buildings they splashed upward, imposing an upward force against the slab for which it was not reinforced, causing it to crack and fail.

Modular-unit construction: prefabricating the urban shore

The method of building a house, duplex, or larger condominium structure by fabricating modular units in a shop and assembling them at the site is gaining in popularity for development on shoreline property. The larger of these structures are commonly 2 to 3 stories in height and may contain a large number of living units.

Modular construction makes good economic sense, and there is nothing inherently wrong in this approach to coastal construction. These methods have been used in the manufacturing of mobile homes for years, although final assembly on mobile homes is done in the shop rather than in the field. Doing as much of the work as possible in a shop can save considerable labor and cost. The workers are not affected by outside weather conditions. They can be paid by piecework, enhancing their productivity. Shop work lends itself to labor-saving equipment such as pneumatic nailing guns and overhead cranes.

If the manufacturer desires it, shop fabrication can permit higher quality. Inspection and control of the whole process are much easier. For instance, there is less hesitation about rejecting a poor piece of lumber when you have a nearby supply than if you are building a single dwelling and have just so much lumber on the site.

On the other hand, because so much of the work is done out of the sight of the buyer, there is the opportunity for the manufacturer to take shortcuts if he is so inclined. It is possible that some modular dwelling units have their wiring, plumbing, ventilation, and heating and air conditioning installed at the factory by unqualified personnel, and it is possible the resulting inferior work is either not inspected or inspected by an unconscientious or inept individual. Therefore, it is important to consider the following: Were wiring, plumbing, heating and air conditioning, and ventilation installed at the factory or at the building site? Were the installers licensed and certified? Was the work inspected at both the factory and on the construction site?

Most important, is the modular dwelling unit built to provide safety in the event of fire? For example, just a few of the many safety features that should be included are 2 or more exits, stairs remote from each other, masonry fire walls between units, noncombustible wall sheeting, and compartmentalized units so that if fire does occur it will be confined to that unit.

In general, it is very desirable to check the reputation and integrity of the manufacturer just as you would when hiring a contractor to build your individual house on site. The acquisition of a modular unit should be approached with the same caution as for other structures.

The Standard Building Code, which is followed in most areas, governs prefabricated structures. Prefabricated construction must conform to the same regulations as other types of housing with some exceptions such as testing by a recognized testing laboratory.

If you are thinking of buying a modularized dwelling unit, you are well advised to take the following steps:

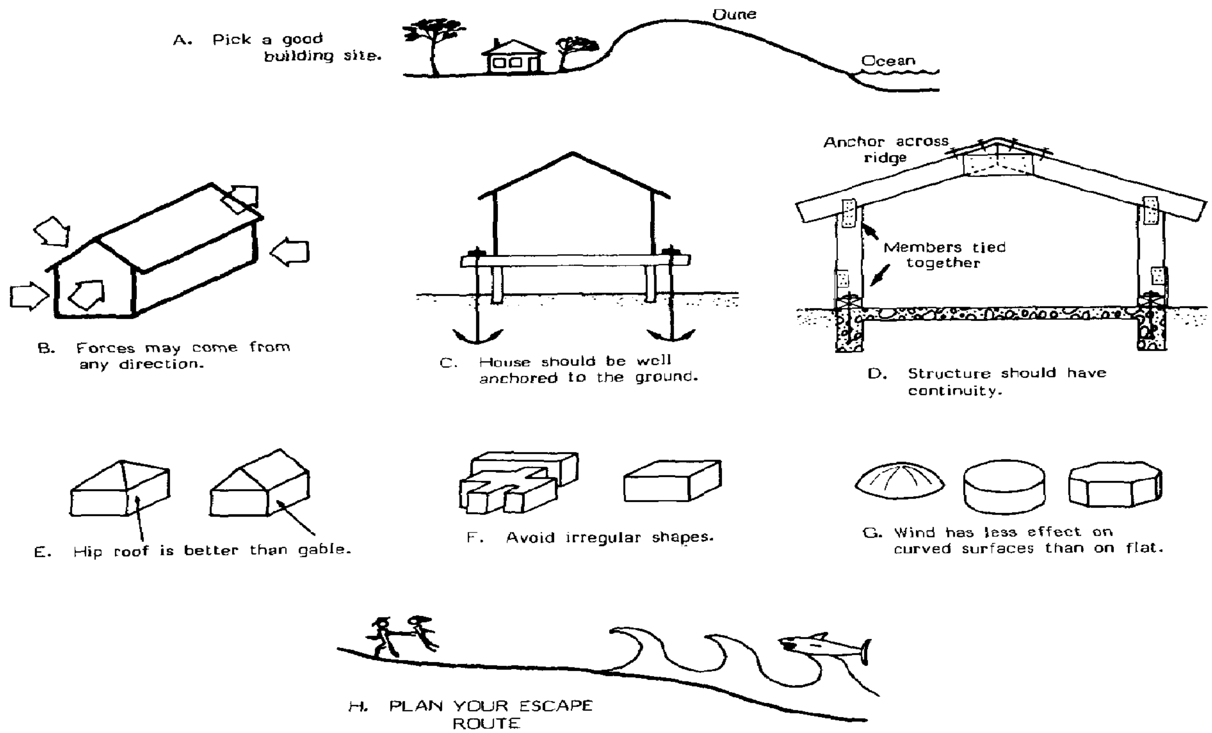


Fig. 6.16. Some rules for selecting or designing a house.

1. Check the reputation and integrity of the developer and manufacturer.
2. Check to see if the developer has a state contractor's license.
3. Check the state law on who is required to approve and certify the building.
4. Check what building codes are enforced.
5. Check to see if the state fire marshal's office has indicated that the dwelling unit complies with all applicable codes. Also check to see if this office makes periodic inspections.
6. Check to see that smoke alarms have been installed, if windows are the type that can be opened, if the bathroom has an exhaust fan, and if the kitchen has a vent through the roof.

For the location of modular units, as with all other types of structures, also consider site safety and escape route(s).

An unending game: only the players change

Hurricane or calm, receding shore or growing shore, storm-surge flood or sunny sky, migrating dune or maritime forest, win or lose, the gamble of coastal development will continue. If you choose your site with natural safety in view, follow structural engineering design in construction, and take a generally prudent approach to living at the shore (fig. 6.16), then you become the gambler who knows when to hold them, when to fold them, and when to walk away.

Our goal is to provide guidance to today's and tomorrow's players. This book is not the last or by any means the complete guide to coastal living, but it should provide a beginning. In the appendixes that follow are additional resources that we hope every reader will pursue.

Appendix A. Hurricane checklist

Keep this checklist handy for protection of family and property.

When a hurricane threatens

__ Listen for official weather reports.
__ Read your newspaper and listen to radio and television for official announcements.
__ Note the address of the nearest emergency shelter.
__ Know the official evacuation route in advance.
__ Pregnant women, the ill, and the infirm should call a physician for advice.
__ Be prepared to turn off gas, water, and electricity where it enters your home.
__ Fill tubs and containers with water (one quart per person per day).
__ Make sure your car's gas tank is full.
__ Secure your boat. Use long lines to allow for rising water.
__ Secure movable objects on your property:

- __ doors and gates
- __ outdoor furniture
- __ shutters
- __ garden tools
- __ hoses
- __ garbage cans
- __ bicycles or large sports equipment
- __ barbecues or grills
- __ other

__ Board up or tape windows and glassed areas. Close storm shutters. Draw drapes and window blinds across windows and glass doors. Remove furniture in their vicinity.
__ Stock adequate supplies:

- __ transistor radio
- __ fresh batteries
- __ canned heat
- __ hammer
- __ boards
- __ pliers
- __ hunting knife
- __ tape
- __ first-aid kit
- __ prescribed medicines
- __ water purification tablets
- __ insect repellent
- __ gum, candy
- __ life jackets
- __ charcoal bucket and charcoal
- __ buckets of sand
- __ flashlights
- __ candles
- __ matches
- __ nails
- __ screwdriver
- __ ax*
- __ rope*
- __ plastic drop cloths, waterproof bags, ties
- __ containers for water
- __ disinfectant
- __ canned food, juices, soft drinks (see below)
- __ hard-top headgear
- __ fire extinguisher
- __ can opener and utensils

__ Check mobile-home tiedowns.

*Take an ax (to cut an emergency escape opening) if you go to the upper floors or attic of your home. Take rope for escape to ground when water subsides.

Suggested storm food stock for family of four

__ two 13-oz. cans evaporated milk
__ four 7-oz. cans fruit juice
__ 2 cans tuna, sardines, Spam, chicken
__ three 10-oz. cans vegetable soup
__ 1 small can of cocoa or Ovaltine
__ one 15-oz. box raisins or prunes
__ salt
__ pet food?
__ one 14-oz. can cream of wheat or oatmeal
__ one 8-oz. jar peanut butter or cheese spread
__ two 16-oz. cans pork and beans
__ one 2-oz. jar instant coffee or tea
__ 2 packages of crackers
__ 2 pounds of sugar
__ 2 quarts of water per person

Special precautions for apartments/condominiums

__ Make one person the building captain to supervise storm preparation.
__ Know your exits.
__ Count stairs on exits; you'll be evacuating in darkness.
__ Locate safest areas for occupants to congregate.
__ Close, lock, and tape windows.
__ Remove loose items from terraces (and from your absent neighbors' terraces).
__ Remove or tie down loose objects from balconies or porches.
__ Assume other trapped people may wish to use the building for shelter.

Special precautions for mobile homes

__ Pack breakables in padded cartons and place on floor.
__ Remove bulbs, lamps, mirrors—put them in the bathtub.
__ Tape windows.
__ Turn off water, propane gas, electricity.
__ Disconnect sewer and water lines.
__ Remove awnings.
__ **Leave.**

Special precautions for businesses

__ Take photos of building and merchandise.
__ Assemble insurance policies.
__ Move merchandise away from plate glass.
__ Move merchandise to as high a location as possible.
__ Cover merchandise with tarps or plastic.
__ Remove outside display racks and loose signs.
__ Take out lower file drawers, wrap in trash bags, and store high.
__ Sandbag spaces that may leak.
__ Take special precautions with reactive or toxic chemicals.

If you remain at home

__ Never remain in a mobile home; seek official shelter.
__ Stay indoors. Remember, the first calm may be the hurricane's eye. Remain indoors until an official all-clear is given.

— Stay on the "downwind" side of the house. Change your position as the wind changes.
— If your house has an "inside" room, it may be the most secure part of the structure.
— Keep continuous communications watch for *official* information on radio and television.
— Keep calm. Your ability to meet emergencies will help others.

If evacuation is advised

— Leave as soon as you can. Follow official instructions only.
— Follow official evacuation routes unless those in authority direct you to do otherwise.
— Take these supplies:
  — change of warm, protective clothes
  — first-aid kit
  — baby formula
  — identification tags: include name, address, and next of kin (wear them)
  — flashlight
  — food, water, gum, candy
  — rope, hunting knife
  — waterproof bags and ties
  — can opener and utensils
  — disposable diapers
  — special medicine
  — blankets and pillows in waterproof casings
  — radio
  — fresh batteries
  — bottled water
  — purse, wallet, valuables
  — life jackets
  — games and amusements for children
— Disconnect all electric appliances except refrigerator and freezer. Their controls should be turned to the coldest setting and the doors kept closed.
— Leave food and water for pets. Seeing-eye dogs are the only animals allowed in the shelters.
— Shut off water at the main valve (where it enters your home).
— Lock windows and doors.
— Keep important papers with you:
  — driver's license and other identification
  — insurance policies
  — property inventory
  — Medic Alert or other device to convey special medical information

During the hurricane

— Stay indoors and away from windows and glassed areas.
— If you are advised to evacuate, **do so at once**.
— Listen for continuing weather bulletins and official reports.
— Use your telephone only in an emergency.
— Follow official instructions only. Ignore rumors.

__ Keep **open** a window or door on the side of the house opposite the storm winds.
__ Beware of the "**eye of the hurricane.**" A lull in the winds does not necessarily mean that the storm has passed. Remain indoors unless emergency repairs are necessary. Exercise caution. Winds may resume suddenly, in the opposite direction and with greater force than before. Remember, if wind direction does change, the open window or door must be changed accordingly.
__ Be alert for rising water.
__ If electric service is interrupted, note the time.
  __ Turn off major appliances, especially air conditioners.
  __ Do not disconnect refrigerators or freezers. Their controls should be turned to the coldest setting and doors closed to preserve food as long as possible.
  __ Keep away from fallen wires. Report location of such wires to the utility company.
__ If you detect **gas**:
  __ Do not light matches or turn on electrical equipment.
  __ Extinguish all flames.
  __ Shut off gas supply at the meter.*
  __ Report gas service interruptions to the gas company.
__ **Water**:
  __ The only **safe** water is the water you stored before it had a chance to come in contact with flood waters.
  __ Should you require an additional supply, be sure to boil water for 30 minutes before use.
  __ If you are unable to boil water, treat water you will need with water purification tablets.

Note: An official announcement will proclaim tap water "safe." Treat all water except stored water until you hear the announcement.

After the hurricane has passed

__ Listen for official word of danger having passed.
__ Watch out for loose or hanging power lines as well as gas leaks. People have survived storms only to be electrocuted or burned. Fire protection may be nil because of broken power lines.
__ Walk or drive carefully through the storm-damaged area. Streets will be dangerous because of debris, undermining by washout, and weakened bridges. Watch out for poisonous snakes and insects driven out by flood waters.
__ Eat nothing and drink nothing that has been touched by flood waters.
__ Place spoiled food in plastic bags and tie securely.
__ Dispose of all mattresses, pillows, and cushions that have been in flood waters.
__ Contact relatives as soon as possible.

Note: If you are stranded, signal for help by waving a flashlight at night or white cloth during the day.

*Gas should be turned back on only by a gas serviceman or licensed plumber.

Appendix B. A guide to federal, state, and local agencies involved in coastal development

Numerous agencies at all levels of government as well as in the private sector are engaged in planning, regulating, or studying coastal development in Alabama and Mississippi. Some of these governmental agencies issue permits for various phases of construction. Others provide information on development (or environmental characteristics pertinent to development) to the homeowner, developer, or planner. Following is an alphabetical list of topics related to coastal development; under each topic are the names of agencies to consult for information on that topic. Some of these sources also provide similar information on noncoastal areas.

Appendix C presents a list of references, some of which provide additional agency listings as well as basic information of interest to the coastal dweller. In particular, readers needing a more complete list of federal and state agencies involved in coastal development should get in touch with either the Alabama Department of Environmental Management or the Mississippi Bureau of Marine Resources.

Aerial photography and remote-sensing imagery

If you are interested in aerial photography, remote-sensing imagery, or agencies that supply aerial photographs or images, write or call the appropriate office listed below.

For historic listings of available photography (type, scale, year flown, coverage, percentage of cloud cover, etc.) contact:

National Cartographic Information Center
U.S. Geological Survey
507 National Center
Reston, VA 22092
Phone: (703) 860–6045

Request "APSRS Aerial Photography Summary Record System: No. 1/Alabama, Georgia" or "No. 3/Arkansas, Louisiana, Mississippi" and accompanying microfiche (price $2.00).

Recent aerial photography should be available from:

U.S. Department of Agriculture
Agricultural Stabilization and Conservation Service
Aerial Photography Field Office
2222 West, 2300 South
P.O. Box 30010
Salt Lake City, UT 84125
Phone: (801) 524–5856

Request "Status of Aerial Photography Coverage" for Alabama or Mississippi. Black-and-white vertical aerial photographs are available for coastal counties.

Gulf Coast residents are conveniently close to the Public Office of the National Mapping Division, National Cartographic Information Center of the U.S. Geological Survey. The facility will provide assistance in finding aerial photographs, space imagery, as well as maps, map products, and geodetic control. The office is located in the South Reception Center of the National Space Technology Laboratories (take NASA exits off Interstate Highways I-10 or I-59). Contact:

National Mapping Division
U.S. Geological Survey Facility
Building 3101
National Space Technology Laboratories
NSTL Station, MS 39529
Phone: (601) 688-3541

Offices that may have aerial photography available for inspection but are generally not suppliers of photographs include:

Alabama Department of Environmental Management
Field Office
4358 Midmost Drive
Mobile, AL 36609
Phone: (205) 343-7841

Alabama Department of Economic and Community Affairs
3465 Norman Bridge Road
Montgomery, AL 36130
Phone: (205) 284-8700

Mississippi Coastal Program
Bureau of Marine Resources
P.O. Box 959
Long Beach, MS 39560
Phone: (601) 864-4602

Other sources that may be more conveniently located and that may have aerial photographs of your area available for inspection include the office of the tax assessor in your county, departments of geography or geology in local colleges and universities, the Mobile district office of the U.S. Army Corps of Engineers, and the following.

Geological Survey of Alabama
P.O. Drawer O
University, AL 35486
Phone: (205) 349-2852

Geological, Economic and Topographic Survey
P. O. Box 4915
Jackson, MS 39216
Phone: (601) 354-6228

For information on satellite imagery and the National High Altitude Photography Program, contact:

EROS Data Center
U.S. Geological Survey
Sioux Falls, SD 57198
Phone: (605) 594-6151

Archives and records

Historic information on coastal counties and possible sources for historic maps and photographs are:

Department of Archives and History
Archives and History Building
624 Washington Avenue
Montgomery, AL 36130
Phone: (205) 261-4361

Department of Archives and History
100 South State Street
P.O. Box 571
Jackson, MS 39205
Phone: (601) 354-6218

Beach erosion

Information on beach erosion, pass history, floods, and high winds is available from:

Alabama Department of Environmental Management
State Capitol
Montgomery, AL 36130
Phone: (205) 271-7700 or (field office, Mobile) 343-7841

Alabama Department of Economic and Community Affairs
3465 Norman Bridge Road
Montgomery, AL 36130
Phone: (205) 284-8700

Mississippi Coastal Program
Bureau of Marine Resources
P.O. Box 959
Long Beach, MS 39560
Phone: (601) 864-4602

U.S. Army Corps of Engineers
Mobile District
P.O. Box 2288
Mobile, AL 36628
Phone: (205) 690-2529

Mississippi-Alabama Sea Grant Consortium
P.O. Drawer AG
Ocean Springs, MS 39564
Phone: (601) 875-9341

Remote-Sensing/Topographic Division
Geological Survey of Alabama
P.O. Drawer O
University, AL 35486
Phone: (205) 349-2852

Coastal Erosion Information System
Department of Environmental Sciences
University of Virginia
Charlottesville, VA 22903
(Summary of historic patterns of shoreline change along the U.S. coasts prepared for National Atlas)

Bridges and causeways

The U.S. Coast Guard has jurisdiction over the issuing of permits to build bridges or causeways that will affect navigable waters. Information is available from:

Bridge Administration Office
8th U.S. Coast Guard District
Hale Boggs Federal Building
New Orleans, LA 70120
Phone: (504) 589–2965

Building codes and zoning

Counties or municipalities are responsible for such codes and their enforcement. Generally the Standard Building Code (old Southern Building Code) is the basis for local codes. Some local governments add more stringent requirements and may have special regulations on mobile homes. Those communities participating in the National Flood Insurance Program will have elevation requirements in order to meet the specifications of the program. For the specific code in your area, contact the city or county building inspector.

Alabama residents can find a listing of addresses and phone numbers for city clerks, building inspectors, and planning commissions in *Building in the Coastal Counties* (reference 88, appendix C).

Civil Preparedness. See also *Disaster assistance*

Director, Civil Defense Department
State Administrative Building.
64 North Union Street
Montgomery, AL 36130
Phone: (205) 269–7787

Director, Mississippi Civil Defense Council
P.O. Box 4501, Fondren Station
Jackson, MS 39216
Phone: (601) 354–7200

Baldwin County Civil Defense
P.O. Box 426
24 North Section
Fairhope, AL 36532
Phone: (205) 928–7661

Mobile County Emergency Agency
348 North McGregor Avenue
Mobile, AL 36608
Phone: (205) 460–8000

Jackson County Disaster Emergency Services
600 Convent Avenue
Pascagoula, MS 39567
Phone: (601) 769–7900, ext. 200 or 210

Hancock County Civil Defense
Old Spanish Trail

Bay St. Louis, MS 39520
Phone: (601) 467-9226

Harrison County Civil Defense
P.O. Box 68
Gulfport, MS 39501
Phone: (601) 865-4002

Coastal zone management

In Alabama the coastal zone is managed through the permitting authority of the Alabama Department of Environmental Management, and in Mississippi by the equivalent authority of the Mississippi Coastal Program through the Bureau of Marine Resources. These agencies coordinate the permitting process with the U.S. Army Corps of Engineers and other state and federal offices that have general regulatory authority in the coastal zone (for example, those dealing with fish and game, water and air quality, and resource development, including groundwater). In Alabama the Department of Economic and Community Affairs oversees nonregulatory and nonpermitting activities for the coastal zone (for example, planning).

Before undertaking any activity that will change the character of the coastal zone land or waters (for example, construction, dredge and fill, well drilling, septic tank installation, water discharge, and similar activities), contact these lead agencies for instructions on necessary permits and permit application.

Alabama Department of Environmental Management
State Capitol
Montgomery, AL 36130
Phone: (205) 271-7700

Alabama Department of Environmental Management
Field Office
4358 Midmost Dr.
Mobile, AL 36609
Phone: (205) 343-7841

Mississippi Coastal Program
Bureau of Marine Resources
P.O. Box 959
Long Beach, MS 39560
Phone: (601) 864-4602

For additional information on management and planning write the above offices or contact:

Alabama Department of Economic and Community Affairs
3465 Norman Bridge Road
Montgomery, AL 36130

Office of Ocean and Coastal Resource Management
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
3300 Whitehaven Street, N.W.
Washington, DC 20235

Consultants

It is not appropriate for the authors of this publication to endorse any individual or firm as a recommended coastal or construction consultant. We do encourage prospective buyers as well as owners of existing property to seek expert advice on safe housing construction, selection of safe sites with respect to coastal hazards, and nonstructural techniques for maintaining beaches and dunes.

The offices listed in this appendix under other topics and the offices of your local government are sources of advice on many of the problems you are likely to encounter. Your state colleges and universities and their affiliated marine laboratories, particularly those with coastal geologists and coastal engineers, may be valuable sources of information. Conservation organizations such as the National Audubon Society should not be overlooked. Such agencies may be able to put you in touch with reputable consultants.

Disaster assistance. See also *Civil preparedness*

Federal Emergency Management Agency
Region IV Office
1375 Peachtree Street, N.E.
Atlanta, GA 30309
Phone: (404) 881–2391

American National Red Cross
Disaster Services
Washington, DC 20006
Phone: (202) 857–3722

Dredging, filling, and construction in coastal waterways

State coastal zone management agencies and the U.S. Army Corps of Engineers have permitting authority to regulate various activities in coastal waters and wetlands. The state agency usually coordinates permitting if more than 1 agency is involved, so before engaging in any activity in these areas contact:

Alabama Department of Environmental Management
State Capitol
Montgomery, AL 36130
Phone: (205) 271–7700, or call the Mobile field office for information (343–7841)

Mississippi Coastal Program
Bureau of Marine Resources
P.O. Box 959
Long Beach, MS 39560
Phone: (601) 864–4602

In some cases you will need a building permit. Contact your county or municipality building inspector's office and inquire if a permit is needed for your project. You also may need a permit from the state docks department. The offices listed above will be able to inform you of such requirements.

Federal law requires that any person who wishes to dredge, fill, or place any structure in navigable water (almost any body of coastal water including bays, sounds, and estuaries) must apply for a permit from the U.S. Army Corps of Engineers. Information is available from:

U.S. Army Engineer District, Mobile
P.O. Box 2288
Mobile, AL 36628
Phone: (205) 690–2529

U.S. Army Engineer District, Vicksburg
P.O. Box 60
Vicksburg, MS 39180
Phone: (601) 634–5000

Both state and federal permit application reviews require lead time. You should expect action on such applications to take at least 45 days, and as long as 120 days.

Dune alteration

Sand dunes are recognized as important natural protection against storm waves and storm-surge flooding, as well as sand reservoirs for natural beach maintenance. Both Alabama and Mississippi have regulations against dune alteration and removal, although the wording of their coastal zone regulatory guidelines are different.

Alabama generally requires preservation and restoration of dunes as part of the erosion control program. Any construction on dunes requires a permit from the Alabama Department of Environmental Management (ADEM). Construction is not permitted seaward of a "construction setback" line that is 40 feet inland of the crestline of the primary dune. When applying to build in a dunes area, the applicant must provide a survey of his property, completed by a duly licensed surveyor of the State of Alabama, showing the primary dune "crestline" and the location of the proposed construction. This survey must be submitted to ADEM no more than 90 days before the permit application is filed. ADEM can grant variances to the setback requirement under special circumstances, however, "it shall be in violation of the Coastal Area Management Program to alter the primary dune system through the removal of dune or beach sands and grasses, through the operation of vehicles on the dune system, or any activity that could result in the destruction of the dune" (reference 88, appendix C).

Before engaging in any activity which may affect coastal sand dunes contact:

Alabama Department of Environmental Management
State Capitol
Montgomery, AL 36130
Phone: (205) 271–7700

In Mississippi's coastal management program a criterion for delineating Areas of Particular Concern (APCs) is the identification of areas needed to protect, maintain, or replenish coastal lands or resources. Sand dunes and beaches are regarded as such areas and therefore fall under the state's permitting authority. Dune areas are less common along the urbanized Mississippi coast, but before engaging in any construction on or alteration of dunes, contact:

Mississippi Coastal Program
Bureau of Marine Resources
P.O. Box 959

Long Beach, MS 39560
Phone: (601) 864-4602

Local communities also may have sand dune ordinances in addition to the state law. Contact your local municipal and county planning offices.

Environmental affairs

Administrator
Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460
Phone: (202) 755-2673

EPA Region 4 Office
1421 Peachtree Street, N.E.
Atlanta, GA 30309
Phone: (404) 526-5727

Environmental Health Administration
Department of Public Health
State Office Building
501 Dexter Avenue
Montgomery, AL 36130
Phone: (205) 261-5004

Air and Water Pollution Control Commission
Robert E. Lee Building
Jackson, MS 39201
Phone: (601) 354-6783

Flood insurance. See *Insurance*

Geologic information

Branch of Distribution
U.S. Geological Survey
1200 South Eads Street
Arlington, VA 22202
(Request "Geologic and water-supply reports and maps, Alabama," or the same title for Mississippi; free index)

U.S. Geological Survey
Southeastern Region
Richard B. Russell Federal Building, Suite 772
75 Spring Street, S.W.
Atlanta, GA 30309

Gulf Coast Hydroscience Center
National Space Technology Laboratories
Bay St. Louis, MS 39529

Geological Survey of Alabama
P.O. Drawer O
University, AL 35486
Phone: (205) 349-2852

Geological, Economic, and Topographic Survey
2525 North West Street
P.O. Box 4915
Jackson, MS 39216
Phone: (601) 354-6228

Gulf Coast Research Laboratory
Ocean Springs, MS 39564
Phone: (601) 875-9341

Department of Geology
University of Alabama
University, AL 35486
Phone: (205) 348-5095

Department of Geology and Geography
University of South Alabama
Mobile, AL 36688
Phone: (205) 460-6381

Department of Geology and Geological Engineering
University of Mississippi
University, MS 38677
Phone: (601) 232-7498

Department of Geology and Geography
Mississippi State University
Mississippi State, MS 39762
Phone: (601) 325-5926

Hazards. See *Beach erosion* and *Insurance*

Office of Ocean and Coastal Resources Management
National Oceanic and Atmospheric Administration
3300 Whitehaven Street, N.W.
Washington, D.C. 20235

Natural Hazards Research and
Applications Information Center
Institute of Behavioral Science #6
Campus Box 482
University of Colorado
Boulder, CO 80309

Health. See also *Sanitation and septic system permits*

The local health department in your city and/or county will provide information on home waste treatment systems, requirements for hookups to municipal systems, water supply systems, and similar health matters. Questions relating to water quality may be addressed to these offices, or:

Environmental Health Administration
Department of Public Health
State Office Building
501 Dexter Avenue
Montgomery, AL 36130
Phone: (205) 261-5004

Air and Water Pollution Control Commission
Robert E. Lee Building
Jackson, MS 39201
Phone: (601) 354-6783

History. See *Archives and records*

Housing. See *Subdivisions*

Hurricane information. See *Civil preparedness*

The National Oceanic and Atmospheric Administration is the best agency from which to request information on hurricanes. NOAA Storm-Evacuation Maps are prepared for vulnerable areas and cost $2.00 each. Alabama-Mississippi maps are as follows:

T15001 Slidell (Louisiana to southwest Mississippi coast)
T15002 Gulfport (Lakeshore-Waveland to Mississippi City)
T15003 Biloxi (Edgewater Park to Pascagoula)
T15004 Bayou La Batre (Point aux Chenes to Fort Morgan including Dauphin Island and southwest Mobile Bay)
T15005 Mobile (upper Mobile Bay, north of Fairhope)

Maps for the southeastern part of Mobile Bay and the adjacent Fort Morgan Peninsula–Gulf Shores–Perdido Key are not yet available. To obtain the map(s) for your area of interest, call or write:

Distribution Division (C-44)
National Ocean Survey
National Oceanic and Atmospheric Administration
Riverdale, MD 20840
Phone: (301) 436–6990

Other federal sources include:

National Hurricane Center
1320 South Dixie Highway
Miami, FL 33146

Environmental Data Service
National Climatic Center
Federal Building
Asheville, NC 28801

The weather departments of your local television and radio stations and U.S. Coast Guard offices will provide forecast information, and sometimes provide informational literature. We recommend the free brochure "Hurricane Survival Checklist" available from the Insurance Information Institute (see reference 13, appendix C; see also appendix A).

County Civil Defense offices are the local coordinating agencies for defining evacuation routes. Check with your county's office for information (addresses listed under *Civil preparedness* in this appendix).

Insurance

Information on windstorm insurance can be obtained through your insurance agent.

Flood insurance is available in communities that participate in the National Flood Insurance Program (NFIP). These communities have adopted special building requirements for construction in flood-prone areas. By complying with these local regulations, property owners also will ensure that flood insurance premiums are affordable.

For information on obtaining flood insurance, contact your insurance agent. Further information is available by calling, toll free, 1–800–638–6620, or by writing:

National Flood Insurance Program
Federal Emergency Management Agency
Federal Insurance Administration
Washington, DC 20472

For flood insurance maps, elevation certificates, and other forms, write:

National Flood Insurance
P.O. Box 34604
Bethesda, MD 20817

For information on community participation, building requirements, and floodplain mapping, contact your local building or zoning department or:

FEMA Region IV
1375 Peachtree Street, N.E.
Atlanta, GA 30309
Phone: (404) 881-2391

Alabama Department of Economic and Community Affairs
3465 Norman Bridge Road
Montgomery, AL 36130
Phone: (205) 284-8700

Mississippi Research and Development Center
P.O. Drawer 2470
Jackson, MS 39205
Phone: (601) 982-6376

Your insurance agent and community building inspector should be able to provide you with information on the location of your building site on the Flood Insurance Rate Map (FIRM) or Flood Hazard Boundary Map (FHBM), as well as the required elevation for the first floor of your structure.

Note that a flood insurance policy under the National Flood Insurance Program is separate from your regular homeowner's insurance policy.

Land acquisition

When acquiring property or a condominium—whether in a subdivision or not—consider the following: (1) Owners of property next to dredged canals should make sure that the canals are designed for adequate flushing to keep the waters from becoming stagnant. (2) Descriptions and surveys of land in coastal areas are often complicated. Old titles to lands along the waterline may be upheld in court; titles should be carefully reviewed by a competent attorney before they are transferred. A boundary described as the high-water mark may be impossible to determine. (3) Ask about the provision of services such as sewage disposal, garbage pickup, fire protection, and utilities including water supply, electricity, gas, and telephone. (4) Be sure that any promises of future improvements, access, utilities, additions, common property rights, maintenance, and similar services, are in writing. (5) Find out who will bear the costs of future erosion control, post-storm cleanup and reconstruction, and restoration of roads, bridges, and all services. (6) Be sure to visit the property and inspect it carefully before buying it (see the following sections on *Planning and land use* and *Subdivisions*).

Maps

A wide variety of maps are useful to planners and managers and may be of interest to individual property owners. Topographic, geologic, coastal zone (topobathy), land-use maps, and orthophoto quadrangles are available from:

Distribution Section
U.S. Geological Survey
1200 South Eads Street
Arlington, VA 22202

A free index to the type of map desired (for example, the "Index to Topographic Maps of Alabama") should be requested and then used for ordering specific maps. Similar maps are available from:

Geological Survey of Alabama
P.O. Drawer O
University, AL 35486
Phone: (205) 349–2852

Geological, Economic, and Topographic Survey
2525 North West Street
P.O. Box 4915
Jackson, MS 39216
Phone: (601) 349–2852

Evacuation maps: Call your County Department of Emergency Preparedness (also see *Hurricane information*).

Flood-zone maps: see *Insurance*.

Planning maps: call or write your local county commission.

Soil maps and septic suitability: see *Soils*.

Nautical charts in several scales contain navigation information on Gulf coastal waters. A nautical chart index map is available from:

National Ocean Survey
Distribution Division (C-44)
National Oceanic and Atmospheric Administration
6501 Lafayette Avenue
Riverdale, MD 20840
Phone: (301) 436–6990

There also is the *Geological Highway Map of the Southeastern Region*, compiled by A. P. Bennison and others, and published by the American Association of Petroleum Geologists. Although this map is not aimed specifically at the coast, it provides the layman with a semitechnical treatment of the regional geology of the Gulf Coast. In addition to the map, there is a discussion of the geological development of the region and its rock and mineral resources, a photographic map, subsurface cross sections, descriptions of gemstones and fossils, and a list of points of geologic interest. Available from:

American Association of Petroleum Geologists
P.O. Box 979
Tulsa, OK 74101

Contact the Alabama or Mississippi state highway departments for county road maps:

Alabama Highway Department
State Highway Building
11 South Union Street
Montgomery, AL 36130
Phone: (205) 832–5440

Mississippi Highway Department
1004 Woolfolk State Office Building
501 North West Street
Jackson, MS 39201
Phone: (601) 354–6034

Marine and coastal zone information

In addition to the government agencies listed by topic in this appendix, many private agencies, laboratories, and educational institutions are valuable sources for reports, descriptive pamphlets, contacts for having questions answered, and sponsors of coastal programs including lectures, seminars, and film series. The following list is not meant to be complete but suggests the range of possibilities:

Mississippi-Alabama Sea Grant Program
Caylor Building
Gulf Coast Research Laboratory
Ocean Springs, MS 39564
Phone: (601) 875–9341

Marine Environmental Sciences Consortium
Dauphin Island Sea Lab
P.O. Box 369-370
Dauphin Island, AL 36528
Phone: (205) 861–2141

J. L. Scott Marine Education Center
1650 East Beach Boulevard
Biloxi, MS 39530
Phone: (601) 374–5552

Information
Gulf Coast Research Laboratory
Ocean Springs, MS 39564
Phone: (601) 875–2244

Mississippi Sand Hill Crane Refuge
P.O. Box 699
Gauthier, MS 39553

Gulf Islands National Seashore
4000 Hanley Road
Ocean Springs, MS 39564
Phone: (601) 875–9057

Marine Resources Division
Alabama Department of Conservation
and Natural Resources
P.O. Box 189
Dauphin Island, AL 36528
Phone: (205) 861–2882

Mariculture Center
P.O. Drawer 458
Gulf Shores, AL 36542
Phone: (205) 968–7575

ADEM Field Office
4358 Midmost Drive
Mobile, AL 36609
Phone: (205) 343–7841

Bureau of Marine Resources
P.O. Box 959
Long Beach, MS 39560
Phone: (601) 864–4602

Movies and audiovisual materials

It's Your Coast is a 28-minute film produced by the National Oceanic and Atmospheric Administration (NOAA) on coastal zone management problems. The film is available through NOAA and state film libraries or from the Marine Advisory Program, University of Florida, Gainesville, FL 32611. Other NOAA films of interest include *Tornadoes, Hurricane Before the Storm* (a film centered on Hurricane Eloise), and *The Greatest Storm on Earth* (the problem of the next big hurricane).

Portrait of a Coast is an excellent, 29-minute film that addresses the interrelated problems of rising sea level, coastal erosion, and shoreline stabilization. Although the examples are from the Atlantic Coast, including dramatic footage of a major storm striking the Massachusetts coast, the theme of the film is pertinent to the Gulf Coast. Available from Circle Oak Productions, 73 Girdle Ridge Drive, Katonah, NY 10536 (phone: (914) 232–9451; rental, $48.00).

Coastal Follies is a 20-minute slide-tape presentation that examines the problems of coastal development and offers some guidelines to developers and planners as well as current and prospective property owners. Available from the National Audubon Society, Southeast Regional Office, P.O. Box 1268, Charleston, SC 29402 (rental, $30.00).

Information on audiovisual materials also is available from:

Mississippi-Alabama Sea Grant Consortium
Caylor Building
Gulf Coast Research Laboratory
Ocean Springs, MS 39564
Phone: (601) 875–9341

Educational programs including film schedules are available at:

J. L. Scott Marine Education Center
1650 East Beach Boulevard
Biloxi, MS 39530
Phone: (601) 374–5552

Barrier Islands and Beaches is a slide-tape program that describes many aspects of barrier islands from Massachusetts to Texas. The program can be purchased for $250 from Dinesh Sharma, 2750 Rhode Island Avenue, Fort Myers, FL 33901.

Parks and recreation

Gulf Islands National Seashore, Mississippi-Florida, includes all of the Mississippi barrier islands, except Cat Island, and a small mainland area on Davis Bayou, Mississippi (park headquarters). West Ship Island and historic Fort Massachusetts are accessible on scheduled concession boats that run out of Gulfport and Biloxi (no camping on West Ship Island; nice public beach with lifeguards). East Ship Island, Horn Island, and Petit Bois Island can be reached only by private or charter boat. Primitive camping is permitted on these islands. For information on recreational use of the islands, contact or visit:

Gulf Islands National Seashore
4000 Hanley Road
Ocean Springs, MS 39564
Phone: (601) 875–9057

Information on state parks is available from:

Division of State Parks
Department of Conservation and Natural Resources
Administration Building
64 North Union Street
Montgomery, AL 36130
Phone: (205) 832–6323

Park Commission
717 Robert E. Lee Building
Jackson, MS 39201
Phone: (601) 354–6324

Fort Morgan is located 22 miles west of Gulf Shores on Mobile Point at the entrance to Mobile Bay. The fort was completed in 1834 and was an important fortification during the War Between the States. For information, contact:

Alabama Historical Commission
725 Monroe Street
Montgomery, AL 36130

Fort Morgan
Star Route 2780
Gulf Shores, AL 36542
Phone: (205) 540–7125

Planning and land use. See also *Coastal zone management*

For specific information on your area, check with your local town or county commission. Most local governments have planning boards that answer to the state coastal agencies and have available copies of existing or proposed land-use plans. For more general information, contact:

Department of Economic and Community Affairs
3465 Norman Bridge Road
Montgomery, AL 36130
Phone: (205) 284–8700

Federal-State Programs
Office of the Governor
400 Watkins Building
510 George Street

Jackson, MS 39201
Phone: (601) 354-7570

Roads and property access

Before buying property determine if roads and access rights will be provided. If connecting a driveway to county or state maintained right-of-way, you should contact the appropriate county or state office before construction.

Alabama Highway Department
State Highway Building
11 South Union Street
Montgomery, AL 36130
Phone: (205) 832-5440

Mississippi Highway Department
1004 Woolfolk State Office Building
501 North West Street
Jackson, MS 39201
Phone: (601) 354-6034

Sanitation and septic system permits

Usually before construction permits will be issued, the permit for a septic system (where there is not access to a sewer system) must be obtained from your local health department. Such a permit is issued only if the soil is suitable for the septic system. Old marsh muds and peaty soils are usually unsuitable. Likewise, if your property does not have access to a municipal water system, you will need a well. Check with your county health department to determine the quality of the local groundwater. Make sure that the design and location of your septic system will safeguard your water supply.

Activity resulting in effluent discharge or runoff into surface waters requires certification from the state water pollution control agency that the proposed activity will not violate water quality standards. For information contact:

Alabama Department of Environmental Management
State Capitol
Montgomery, AL 36130
Phone: (205) 271-7700

Mississippi Coastal Program
Bureau of Marine Resources
P.O Box 959
Long Beach, MS 39560
Phone: (601) 864-4602

A permit for the construction of a sewage disposal system or any other structure in navigable waters must be obtained from the U.S. Army Corps of Engineers as well as the state. More information is available from:

U.S. Army Corps of Engineers
Mobile District
Mobile, AL 36628
Phone: (205) 690-2529

A permit for any discharge into navigable waters must be obtained from the U.S. Environmental Protection Agency. Recent judicial interpretation of the Federal Water Pollution Control Amendments of 1972 extends federal jurisdiction above the mean high-water mark for protection of wetland. Federal permits may now be required for the development of land that occasionally is flooded by water draining indirectly into a navigable waterway. Information may be obtained from:

Enforcement Division
Environmental Protection Agency
Region IV
1421 Peachtree Street, N.E.
Atlanta, GA 30309

Soils. See also *Sanitation and septic system permits* and *Vegetation*

Soil type is important in terms of (1) the type of vegetation it can support, (2) the type of construction technique it can withstand (for example, loading, support of piling), (3) its drainage characteristics, and (4) its ability to accommodate septic systems. The following agencies cooperate to produce a variety of maps and reports useful to property owners:

U.S. Department of Agriculture
Soil Conservation Service
138 South Gay Street, Wright Building
P.O. Box 311
Auburn, AL 36830

U.S. Department of Agriculture
Soil Conservation Service
Milner Building, Room 590
P.O. Box 610
Jackson, MS 39205

State Extension Office
(see white pages of your telephone directory)

Soil and Water Conservation District Office
(see white pages of your telephone directory)

Your community or county health department usually can provide information on soils relative to construction and septic permits or refer you to another agency for specific soil information.

Subdivisions

Subdivisions containing more than 50 lots and offered in interstate commerce must be registered with the Office of Interstate Land Sales Registration (as specified by the Interstate Land Sales Full Disclosure Act). Prospective buyers must be provided with a property report. This office also produces a booklet entitled "Get the Facts . . . Before Buying Land" for people who wish to invest in land. Information on subdivision property and land investment is available from:

Office of Interstate Land Sales Registration
U.S. Department of Housing and Urban Development
Washington, DC 20410

Office of Interstate Land Sales Registration
Atlanta Regional Office
U.S. Department of Housing and Urban Development
230 Peachtree Street, N.W.
Atlanta, GA 30303
Phone: (404) 526-4364

Vegetation

Information on vegetation may be obtained from your local soil and water conservation district office. For information on the use of grass and other plantings for stabilization and aesthetics, consult the publications listed in appendix C under *Vegetation*.

Water resources. See *Coastal zone management, Dredging, filling, and construction in coastal waterways, Health,* and *Sanitation*

Wildlife

Mississippi Sand Hill Crane Refuge
P.O. Box 699
Gauthier, MS 39553

Division of Fish and Game
Department of Conservation and Natural Resources
Administrative Building
64 North Union Street
Montgomery, AL 36130
Phone: (205) 832-6300

Game and Fish Commission
308 Robert E. Lee Building
Jackson, MS 39201
Phone: (601) 354-7333

The following research laboratory works on sanitation of oyster reefs, shellfish, and finfish. They will provide information on oyster reefs and sanitary conditions in coastal areas.

Gulf Coast Technical Services Unit
Food and Drug Administration
P.O. Box 158
Dauphin Island, AL 36528
Phone: (205) 861-2961

Zoning. See *Building codes*

Appendix C. Useful references

The following publications are listed by subject, arranged in the approximate order that they appear in the preceding chapters. A brief description of each reference is provided, and sources are included for those readers who would like more information on a particular subject. Many of the references listed are either low in cost or free. We encourage the reader to take advantage of these informative publications.

History

1. *Alabama: A Documentary History to 1900*, by Lucille Griffith, 1972. This volume provides a good introduction to the exploration of the Gulf Coast. Published by the University of Alabama Press, University, AL 35486
2. *Dauphin Island—French Possession, 1699–1763*, 2nd edition, by J. M. Kennedy, 1980. This short history presents an interesting account of the French occupation of Dauphin Island as well as the entire Alabama-Mississippi coastal zone, including incursions up the rivers. Published by Strode Publishers, Inc., Huntsville, AL 35801.
3. *History of Louisiana*, by C. E. A. Gayarre, 1905. This early history text is a good source for map review in looking at coastal changes and includes accounts of hurricanes. Reprinted in 1965 by Pelican Publishing Company, New Orleans.
4. *Concise Natural History of East and West Florida*, by Bernard Romans, 1775. This very early history includes accounts of hurricanes. Reprinted in 1961 by Pelican Publishing Company, New Orleans.
5. *Bay St. Louis, Mississippi, Celebrating 100 Years of Incorporation*, sponsored by the Bay St. Louis Centennial Corporation, 1958. This community publication includes some interesting accounts of early coastal history in Mississippi and photographs of the destruction caused by hurricanes in 1909, 1915, and 1947. Out of print, but copies should be available from Bay St. Louis and Hancock County Library.

Hurricanes

6. *Early American Hurricanes, 1492–1870*, by D. M. Ludlum, 1963. An excellent summary of the stormy history of the Atlantic and Gulf coasts that provides a lesson on the frequency, intensity, and destructive potential of hurricanes. Published by the American Meteorological Society, Boston. Available in public and university libraries.
7. *Hurricane Frederic Post-Disaster Report*, by the U.S. Army Corps of Engineers, Mobile District, 1981. This publication contains a great deal of information concerning the physical, social, and economic effects of Hurricane Frederic on the Mississippi, Alabama, and Florida coasts. A series of maps shows the areas flooded by storm tides. Anyone contemplating buying property in the coastal zone should review this

publication. Copies are available through the U.S. Army Corps of Engineers, Mobile District, P.O. Box 2288, Mobile, AL 36628. Local planning offices also may have copies for inspection.

8. *Natural Disaster Survey Report—Hurricane Frederic: August 29–September 13, 1979*, produced by the National Oceanic and Atmospheric Administration. This NOAA report summarizes the findings of a survey team that came into the area affected by Hurricane Frederic immediately after it crossed the coast. Their objective was to determine how the warning system worked. A brief history of the hurricane's formation and movement is included. The report probably had limited distribution, but local planning and emergency services offices may have inspection copies.

9. *Hurricane Information and Atlantic Tracking Chart*, by the National Oceanic and Atmospheric Administration, 1974. A brochure that describes hurricanes, defines terms, and lists hurricane safety rules. Outlines method of tracing hurricanes and provides a tracking map. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

10. *Bibliography on Hurricanes and Severe Storms of the Coastal Plains Region and Supplement*, by the Coastal Plains Center for Marine Development Services, 1970 and 1972. A list of references that provides a good starting point for people seeking detailed information on hurricanes and hurricane research. Available through college and university libraries.

11. *The Hurricane and Its Impact*, by R. H. Simpson and H. Riehl, 1981. An up-to-date treatment of the greatest of coastal hazards. Chapters include discussions of origin, impact of winds, waves, and tides, assessment and risk reduction, awareness and preparedness, prediction and warning, plus informative appendixes. The volume should be in libraries of coastal communities. Published by Louisiana State University Press, Baton Rouge, LA 70803.

12. *Hurricane Frederic*, edited by Hal Barron, 1979. A magazine format photographic essay on the destruction caused by Frederic in Mobile, Ocean Springs, Pascagoula, Pensacola, and along the Dauphin Island Parkway. Although severe damage is depicted, there are no photographs of the terrible destruction that occurred in Alabama's shoreline communities, such as on Dauphin Island and Gulf Shores. The magazine includes a good description of hurricanes, including an account of the Galveston Hurricane of 1900 that killed at least 6,000 people. Available from C. F. Boone, Publisher, P.O. Box 10411, Lubbock, TX 79408 (price: $3.95 postpaid).

13. *Hurricane Survival Checklist* is a free publication available from the Insurance Information Institute. Call 1–800–221–4954 or send a self-addressed, stamped business-sized envelope to Publications Service Center, Insurance Information Institute, 110 William Street, New York, NY 10038.

14. *Some Climatological Characteristics of Hurricanes and Tropical Storms, Gulf and East Coasts of the U.S.*, by the

National Weather Service, 1975. Technical Report NWS 15 from NWS, NOAA, Washington, D.C.

15. *Report on Hurricane Survey of Mississippi Coast*, by the U.S. Army Corps of Engineers, Mobile District, 1965. The report provides a good summary of hurricanes that have had an impact on the Mississippi coast, including damage summaries. Appendix A is a chronological history of Mississippi hurricanes from 1711 through 1964's Hurricane Hilda. In the 254-year period covered, there were 54 hurricanes, for an average of 1 hurricane every 4.7 years. The report is available for inspection in the U.S. Army Corps of Engineers, Mobile District Office, Mobile, AL 36601.

16. The following are a sampling of additional hurricane-related reports produced by the U.S. Army Corps of Engineers, Mobile District, and available through that office: *After Action Report on Hurricane Camille*, 1970; *Hurricane Camille*, 1970; *Report on Hurricane Survey of Alabama Coast*, 1972; *Report on Hurricane Survey of Mississippi Coast*, 1972; *Post-Disaster Report; Hurricane Eloise, 16–23 September, 1975*, 1976; and *Feasibility Report for Beach Erosion Control and Hurricane Protection—Mobile County, AL*, 1978 (includes Dauphin Island).

Geology and oceanography

17. *Coastal Geology of Mississippi, Alabama, and Adjacent Louisiana Areas*, by Ervin Otvos, Jr., 1982. This technical guidebook was prepared for the New Orleans Geological Society and in part is an update of a similar 1973 guidebook, *Geology of the Mississippi-Alabama Coastal Area and Nearshore Zone*. These guides may be used as an introduction to the geology of the region, but there also are sections on human geography, early history of the region, and historical coastal changes. The 66-page guidebook is available from the Gulf Coast Research Laboratory Bookstore, East Beach Drive, Ocean Springs, MS 39564 (price: $5.00).

18. *Bibliography of Coastal Alabama with Selected Annotations*, by R. L. Lipp and R. L. Chermock, 1975. A good bibliographical starting point for references on the Alabama coastal zone. Available as Alabama Geological Survey Bulletin 108 from the Geological Survey of Alabama, P.O. Drawer O, University, AL 35486.

19. *Mississippi Sound: Salinity Distribution and Indicated Flow Patterns* and *Hydrodynamics of Mobile Bay and Mississippi Sound* are just 2 of many titles dealing with the oceanography of coastal waters that are available from the Mississippi-Alabama Sea Grant Consortium, Caylor Building, Gulf Coast Research Laboratory, Ocean Springs, MS 39564. Write for their free list of publications, or call (601) 875-9341.

20. *Guide to the Marine Resources of Mississippi*, edited by Bobby Irby and Della McCaughan, 1975. This 356-page volume brings together a wide range of information on the Mississippi Gulf Coast. Topics range from history through the

sciences of geology, oceanography, biology, and ecology. Resources are reviewed, followed by a description of many relevant institutions and their programs, including regulatory agencies with addresses and phone numbers. This book is entertaining as well as informative; we recommend it to all Mississippi citizens, especially coastal residents, and visitors. The guide is available from Schools Textbook Supply, P.O. Box 771, Jackson, MS 39202, or check with your local bookstore (price: $16.00).

21. *Symposium on the Natural Resources of the Mobile Estuary, Alabama*, edited by Harold Loyacano, Jr., and J. Paul Smith, 1979. Sponsored by the Alabama Coastal Area Board, Mississippi-Alabama Sea Grant Consortium, and the U.S. Fish and Wildlife Service, this collection of technical papers treats a wide range of topics from bay sediments and their chemistry, to hydrography and circulation in the bay, to pollution. Discussion of the living resources includes marshes, grasses, zooplankton, benthos, fish, oyster, crab, and shrimp fisheries, as well as waterfowl and mammals, and recommendations for management. Available through the sponsoring agencies.

Numerous reports on the geology of the states and the oceanography of the adjacent bays, sounds, and Gulf are available from the Alabama and Mississippi Geological Surveys and various marine laboratories. See appendix B for addresses.

Barrier islands and shoreline evolution

22. *Barrier Island Formation through Nearshore Aggradation-Stratigraphic and Field Evidence*, by Ervin Otvos, 1981. This technical paper outlining the origin and history of the eastern Gulf Coast barrier islands is recommended to serious students of coastal evolution. Published in *Marine Geology*, vol. 43, pp. 145–243. This journal is likely to be found only in college, university, and research libraries.

23. *Geologic Evolution of the Mississippi Sound Area, Mississippi-Alabama; A Brief Account*, by Ervin Otvos, 1982. Together with the previous reference, this paper provides an outline of the geologic evolution of the coast, bays, sounds, and islands. Published in the "Mississippi Sound Symposium Proceedings," Mississippi-Alabama Sea Grant Consortium, Caylor Building, Gulf Coast Research Laboratory, Ocean Springs, MS 39564.

24. *The Offshore Barrier Islands of Mississippi and Alabama*, published by the Marine Education Center, Biloxi, MS. This concise outline gives the origin and some history of these barrier islands, including a map that shows how the islands are migrating to the west. Free as Marine Educational Leaflet No. 9 at the center, or request a copy from the Public Information Office, Gulf Coast Research Laboratory, Ocean Springs, MS 39564.

25. *Barrier Island Handbook*, by Steve Leatherman, 1982. A nontechnical, easy-to-read paperback about barrier island dynamics and coastal hazards. Many of the examples are from the Maryland and New England coasts but are applicable to the Gulf Coast as well. Available from various National Seashores or by mail from Coastal Publications, 5201 Burke Drive, Charlotte, NC 28208 (price: $5.75 postpaid).
26. *Barrier Islands from the Gulf of St. Lawrence to the Gulf of Mexico*, edited by Steve Leatherman, 1979. This collection of technical papers presents some of the current geological research on barrier islands. Of particular interest to students of Gulf Coast barrier islands is the paper by Ervin Otvos entitled, "Barrier Island Evolution and History of Migration, North Central Gulf Coast." Published by Academic Press and available through most college and university libraries.
27. *Barrier Island Genesis: Evidence from the Central Atlantic Shelf*, by Don Swift, 1975. Technical discussion of the origin of Atlantic Coast barrier islands and their migration due to a rising sea level. Published in *Sedimentary Geology*, vol. 14, pp. 1–43, a journal likely to be found only in major college and university libraries.
28. *Barrier Islands and Beaches*, 1976. Proceedings of the May 1976 barrier islands workshop, this is a collection of technical papers prepared by scientists studying islands. Provides an up-to-date, readable overview of barrier islands. Comprehensive coverage from aesthetics to flood insurance by the experts. Topics include island ecosystems, ecology, geology, politics, and planning. Good bibliographical source for those studying barrier islands. Available from the Publications Department, Conservation Foundation, 1717 Massachusetts Avenue, N.W., Washington, DC 20036 (price: $4.00). Request the foundation's free list of publications.

Beaches

29. *Waves and Beaches*, by Willard Bascom, 1964. A discussion of beaches and coastal processes. Published by Anchor Books, Doubleday and Co., Garden City, NY 11530. Available in paperback from local bookstores.
30. *Beaches and Coasts*, 2nd edition, by C. A. M. King, 1972. Classic treatment of beach and coastal processes. Published by St. Martin's Press, 175 Fifth Avenue, New York, NY 10010.
31. *Beach Processes and Sedimentation* by Paul Komar, 1976. The most up-to-date technical explanations of beaches and beach processes. Recommended only to serious students of the beach. Published by Prentice-Hall, Englewood Cliffs, NJ 07632.
32. *Land Against the Sea*, by the U.S. Army Corps of Engineers, 1964. Readable introduction to coastal geology and shoreline processes. However, the author's belief in the value of certain engineering methods is either outdated or unsubstantiated. Available as Miscellaneous Paper No. 4-64 from the U.S.

Army Corps of Engineers, Coastal Engineering Research Center, Kingman Building, Fort Belvoir, VA 22060.

33. *Barrier Beach Development: A Perspective on the Problem*, by S. P. Leatherman, 1981. This article in *Shore and Beach* magazine (vol. 49, no. 2, pp. 2–9) is an excellent statement of the problems of building in the coastal zone. The brief, nontechnical discussion includes an outline of the federal government's role and offers recommendations.

34. *Beaches and Dunes vs. Off Road Vehicles*, by R. D. Donohoe and J. P. Hess, 1981. This pamphlet briefly relates the importance of dunes, vegetation, and beaches to the stability of coastal sites. Alabama's legislation concerning the use of vehicles on the dunes and beaches is outlined. Available from the Alabama Cooperative Extension Service, Auburn University, Auburn, AL 36830 (request MASGP-80-006-4).

35. *The Encyclopedia of Beaches and Coastal Environments*, edited by M. L. Schwartz, 1982. This is a good source book for information and answers to coastal questions, but it is an expensive text and is aimed at the more serious student of the coast. Published by Hutchinson Ross, Stroudsburg, PA 18360, and available through most college and university libraries.

36. *Edge of the Sea*, by Russell Sackett, 1983. This volume in the Time-Life Planet Earth Series outlines the importance and fragility of beaches and barrier systems. Coastal processes, the buffer-zone effect, the significance of coastal breeding grounds, and human impact on these environments are outlined in a nontechnical presentation. Available through your local bookstore or from Time-Life Books, 541 North Fairbanks Court, Chicago, IL 60611 (price: $12.95).

37. *First Aid for Damaged Beaches and Dunes*, by Judy Stout, 1980. A short guide to actions that may be taken to combat short-term erosion. Available from the Alabama Cooperative Extension Service, Auburn University, Auburn, AL 36830 (request MASGP-80-003-02).

Coastal environments

38. *Alabama Coastal Region Ecological Characterization*, by P. O'Neil, M. F. Mettee, J. H. Friend, and others, 1982. A 3-volume set that contains detailed summary information on the coastal ecosystem. Volume 1 is a *Coastal Bibliography*, while volume 2, *A Synthesis of Environmental Data*, contains detailed descriptions of geology, geography, hydrology, climate, biology, and conceptual models of coastal ecosystems. The geology section identifies areas of coastal erosion and accretion. Volume 3, *A Socioeconomic Study*, concentrates on social, demographic, and economic factors at work in the Alabama coastal region. These 3 lengthy reports are available as Information Series Nos. 60, 61, and 62 from Publication Sales, Geological Survey of Alabama, P.O. Drawer O, University, AL 35486.

39. *Delineation of Ecological Critical Areas in the Alabama Coastal Zone*, by Barry Vittor and Judy Stout, 1975. This report provides a good summary of coastal environments

(habitats) in terms of descriptions and distribution. Appendix B of the report is the "Atlas of the Ecological Habitats of Coastal Alabama." The study was published as Report No. 75-002 by the Dauphin Island Sea Lab, Dauphin Island, AL 36528.

40. *Inventory of Alabama's Coastal Resources and Uses*, by the (former) Alabama Coastal Area Board, 1980. This 169-page report covers a wide range of topics, including descriptive topography, geology, soils, and climate of the coast, as well as socioeconomic setting, coastal resource uses, and natural resources. Of particular interest are sections on beaches and dunes, shoreline use, and natural hazard management. Maps showing flood zones and shoreline retreat are included. Copies may still be available through local planning offices or the Alabama Department of Environmental Management.

41. *Mississippi Sound: A Hydrographic and Climatic Atlas*, by C. K. Eleuterius and S. Beaugez, 1980. This oversized book is a storehouse of information on Mississippi Sound and its adjacent shores. The volume includes such information as storm history, including a list of all hurricanes and tropical storms that passed within 100 nautical miles of Mississippi Sound between 1871 and 1979; an account of Hurricane Camille and its storm-surge levels; maps of water properties such as salinities, circulation patterns, and bathymetry; and information on the ecosystem. A limited number of copies were published by the Mississippi-Alabama Sea Grant Consortium. Inspection copies are available in the consortium's offices in Ocean Springs, Mississippi (phone: [601] 875–9341), and on Dauphin Island, Alabama (phone: [205] 861–2141), or these offices can inform you where a copy of the report is available in your area.

42. *Cooperative Gulf of Mexico Estuarine Inventory and Study, Mississippi*, edited by J. Y. Christmas, 1973. A good introduction to the Mississippi coastal zone and Mississippi Sound, this volume, although a technical publication, provides a starting point for obtaining descriptions of coastal environments and processes. The 434-page text is published by and available from the Gulf Coast Research Laboratory, East Beach Drive, Ocean Springs, MS 39564 (price: around $8.00).

43. *Tidal Marshes—The Boundary Between Land and Ocean*, by James Gosselink, 1980. A 13-page brochure that defines tidal marshes, their origin, and importance to man. This nontechnical publication is well illustrated, including organisms commonly found in marshes. For a free copy, contact the Information Transfer Specialist, National Coastal Ecosystems Team, U.S. Fish and Wildlife Service, NASA-Slidell Computer Complex, 1010 Gause Boulevard, Slidell, LA 70458.

44. *The Status of the Barrier Islands of the Southeastern Coast*, by Langdon Warner, 1976. General information on island environments, development pressures, government stimulants to private development, and property assessments. Tables summarize the status of development on barrier islands in

each southeastern coastal state. A readable, useful reference. Persons seeking more detailed information on the development status, property assessments, and local land-use regulations on individual islands may wish to obtain *Barrier Island Inventory* (price: $15.00). Both references are available from the Open Space Institute, 36 West 44th Street, Room 1018, New York, NY 10036.

45. *Know Your Mud, Sand, and Water: A Practical Guide to Coastal Development*, by K. M. Jurgensen, 1976. Clearly and simply written, this pamphlet describes the various island environments relative to development. Recommended to coastal dwellers. Available from UNC Sea Grant, Box 8605, North Carolina State University, Raleigh, NC 27695.
46. *Coastal Ecosystems, Ecological Considerations for Management of the Coastal Zone*, by John Clark, 1974. A clearly written, well-illustrated book on the applications of the principles of ecology to the major coastal zone environments. Available from the Publications Department, The Conservation Foundation, 1717 Massachusetts Avenue, N.W., Washington, DC 20036.

Recreation

47. *Recreation in the Coastal Zone*, 1975. A collection of papers presented at a symposium sponsored by the U.S. Department of the Interior, Bureau of Outdoor Recreation, Southeast Region. Outlines different views of recreation in the coastal zone and the approaches taken by some states to recreation-related problems. The symposium was cosponsored by the Office of Coastal Zone Management. Available from that office, National Oceanic and Atmospheric Administration, 3300 Whitehaven Street, N.W., Washington, DC 20235.
48. *The Audubon Society Field Guide to North American Seashells*, by Harold A. Rehder, 1981. This well-illustrated reference is an excellent handbook for the serious shell collector. Published by Alfred A. Knopf and available in most bookstores.
49. *Mississippi Beaches—Fun in the Sun, Enjoy your Leisure—Go Fishing!*, and *Outdoor Seafood Cookery* are 3 sample titles from the wide range of publications on recreation, fishing guides, recipes, charter boat directories, tide tables, first aid, and similar subjects available from the Sea Grant Marine Advisory Services. For a free publication list or answers to your coastal questions, write the Mississippi-Alabama Sea Grant Consortium, Caylor Building, Gulf Coast Research Laboratory, Ocean Springs, MS 39564, or call (601) 875-9341. The Marine Education and Training Section at the same address has plant and animal identification guides available.

Shoreline engineering

50. *Beach Nourishment Along the Southeast Atlantic and Gulf Coasts*, by Todd Walton and James Purpura, 1977. Appearing in the July 1977 issue of *Shore and Beach* magazine (pp. 10–18) this article examines successes and failures of several

beach nourishment projects, including the postnourishment losses of beach fill along the Harrison County, Mississippi, shore.

51. *Beach Behavior in the Vicinity of Groins*, by C. H. Everts, 1979. An interesting description of the effects of 2 groin fields in New Jersey, which concludes that groins deflect the movement of sand seaward, causing erosion in the downdrift shadow area. This negative downdrift effect occurs even if groin compartments are filled with sand. Published in the Proceedings of the Specialty Conference on Coastal Structures 79 (pp. 853–67) and available from U.S. Army Coastal Engineering Research Center, Kingman Building, Fort Belvoir, VA 22060, as reprint 79-3.

52. *Low-Cost Shore Protection*, by the U.S. Army Corps of Engineers, 1982. A set of 4 reports written for the layman, this title includes the introductory report, a property owner's guide, a guide for local government officials, and a guide for engineers and contractors. The reports are a summary of the Shoreline Erosion Control Demonstration Program and suggest a wide range of engineering devices and techniques to stabilize shorelines, including beach nourishment and vegetation. In adopting these approaches, one should keep in mind that they are short-term measures and may have unwanted side effects. The reports are available from John G. Housley, Section 54 Program, U.S. Army Corps of Engineers, USACE (DAEN-CWP-F), Washington, DC 20314.

53. *Shore Protection Guidelines*, by the U.S. Army Corps of Engineers, 1971. Summary of the effects of waves, tides, and winds on beaches and engineering structures used for beach stabilization. Available free from the Department of the Army, Corps of Engineers, Washington, DC 20318.

54. *Shore Protection Manual*, by the U.S. Army Corps of Engineers, 1973. The "bible" of shoreline engineering. Published in 3 volumes. Request publication 08-0-22-00077 from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 (price: $14.25).

55. *Help Yourself*, by the U.S. Army Corps of Engineers. Brochure addressing the erosion problems in the Great Lakes region. May be of interest to bayshore residents as it outlines shoreline processes and illustrates a variety of shoreline engineering devices used to combat erosion. Free from the U.S. Army Corps of Engineers, North Central Division, 219 South Dearborn Street, Chicago, IL 60604.

56. *Publication List, Coastal Engineering Research Center (CERC) and Beach Erosion Board (BEB)*, by the U.S. Army Corps of Engineers. A list of published research by the Corps. Free from the U.S. Army Corps of Engineers, Coastal Engineering Research Center, Kingman Building, Fort Belvoir, VA 22060.

57. *Perdido Pass Channel, Alabama*, by the U.S. Army Corps of Engineers, 1964. Published as Senate Document 94, 88th Congress, 2nd Session.

Hazard evaluation

58. *Shoreline and Bathymetric Changes in the Coastal Area of Alabama: A Remote-Sensing Approach*, by J. D. Hardin, C. D. Sapp, J. L. Emplaincourt, and K. E. Richter, 1976. This report documents shoreline changes that have taken place since the late nineteenth and early twentieth centuries, both along the oceanfront and in the bays. Plate 1 summarizes the trends and identifies regional stretches of shoreline with erosion rates under 5 feet per year, 5 to 10 feet per year, and more than 10 feet per year. The dynamic changes of Dauphin Island as well as its rapid development by man between 1950 and 1975 are well documented. Residents along the shores of Mobile Bay will find a particularly interesting treatment of the bay's physical character and processes. The report is available as Information Series 50 from Publication Sales, Geological Survey of Alabama, P.O. Drawer O, University, AL 35486.
59. *Shoreline Erosion and Mitigation*, by the Mississippi Bureau of Marine Resources, 1980. Appearing as section 2, chapter 7, in *Mississippi Coastal Program*, this paper identifies general areas of erosion and buildup along the Mississippi shoreline, as well as briefly discussing beach erosion forces, existing erosion control projects, and outlining management techniques. See reference 89.
60. *National Shoreline Study Regional Inventory Report, South Atlantic–Gulf Region*, by the U.S. Army Corps of Engineers, 1971. This report was part of a national study/summary of areas with critical erosion problems. Growth in development since the late 1960s has magnified the problem. The report may be found in some libraries and regional planning offices.
61. *Hurricane Camille Tidal Floods of August 1969 along the Gulf Coast*, by K. V. Wilson and J. W. Hudson, 1969. This series of 14 U.S. Geological Survey Hydrologic Investigations Atlas maps (HA-395 through HA-408) cover all of the Mississippi coast and into Alabama as far as Bayou La Batre. The maps show the area flooded by Hurricane Camille and give spot elevations of peak water heights. Each map includes a printed text describing the hurricane and its associated hazards of flooding and wave effects. Past hurricane tide levels are shown in table form, and positions of emergency water supply wells are shown. The maps are available from the Branch of Distribution, U.S. Geological Survey, 1200 South Eads Street, Arlington, VA 22202.
62. *Hurricane Frederic Tidal Floods of September 12–13, 1979 along the Gulf Coast*, by L. R. Bohman and J. C. Scott, 1980. This series of 21 U.S. Geological Survey Hydrologic Investigations Atlas maps (HA-621 through HA-641) cover the area from eastern Mississippi into the western Florida Panhandle, including all of the ocean and bay coasts of Alabama. The maps include Hurricane Frederic's flood zone, spot elevations of storm-surge height, a printed discussion of the hurricane and its associated hazards, photographs of the resulting destruction, past flood history, and related information. The maps are available from the Branch of Distribution, U.S.

Geological Survey, 1200 South Eads Street, Arlington, VA 22202.

63. *Effects of Hurricane Frederic on Dauphin Island, Alabama*, by W. E. Schramm and others, 1980. This paper provides a good summary of the physical impact of Hurricane Frederic. Published in *Shore and Beach* magazine (vol. 48, no. 3, pp. 20–25).

64. *Surge Effects from Hurricane Eloise*, by W. W. Burdin, 1977. Published in *Shore and Beach* magazine (vol. 45, no. 2, pp. 2–8), this article provides an example of storm surge as a coastal hazard.

65. *Detection of Shoreline Changes from ERTS-1 Data*, by J. L. G. Emplaincourt and C. C. Wielchowsky, 1974. Published in *Southeastern Geographer* (vol. 1, no. 1, pp. 38–45), and also available from the Geological Survey of Alabama, P.O. Drawer O, University, AL 35486, as Reprint Series 29, this article documents shoreline erosion.

66. *Coastal Mapping Handbook*, edited by M. Y. Ellis, 1978. A primer on coastal mapping outlining the various types of maps, charts, and photography available, sources for such products, data and uses, state coastal mapping programs, information appendixes, and examples. A valuable starting reference for anyone interested in maps or mapping. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 (stock no. 024-001-03046-2).

67. *Shoreline Waves, Another Energy Crisis*, by Victor Goldsmith, 1975. Shelf bathymetry is shown to be a controlling factor in wave refraction, which in turn controls wave-height distribution along the beach. Suggests that wave-energy distribution may be controlled by modifying bathymetry. Free from Sea Grant College Program, Virginia Institute of Marine Science, Gloucester Point, VA 23062. Request VIMS Contribution No. 734.

68. *Natural Hazard Management in Coastal Areas*, by G. F. White and others, 1976. The most recent summary of coastal hazards along the entire U.S. coast. Discusses adjustments to such hazards and hazard-related federal policy and programs. Summarizes hazard management and coastal land planning programs in each state. Appendixes include a directory of agencies, an annotated bibliography, and information on hurricanes. An invaluable reference, recommended to developers, planners, and managers. Available from the Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, 3300 Whitehaven Street, N.W., Washington, DC 20235.

69. *Guidelines for Identifying Coastal High Hazard Zones*, by the U.S. Army Corps of Engineers, 1975. Report outlining such zones with emphasis on "coastal special flood-hazard areas" (coastal floodplains subject to inundation by hurricane surge with a 1 percent chance of occurring in any given year). Provides technical guidelines for conducting uniform flood

insurance studies and outlines methods of obtaining 100-year storm-surge elevations. Recommended to island planners. Available from the Galveston District, U.S. Army Corps of Engineers, Galveston, TX 77553.

70. *Report of Investigation of the Environmental Effects of Private Waterfront Lands*, by W. Barada and W. M. Partington, 1972. An enlightening reference that treats the effects of finger canals on water quality. Available from the Environmental Information Center, Florida Conservation Foundation, Inc., 935 Orange Avenue, Winter Park, FL 32789.

Vegetation

71. *First Aid for Damaged Beaches and Dunes*, by Judy Stout, 1980. A booklet to aid homeowners in establishing protective dunes between their cottages and the beach. Available from the Alabama Cooperative Extension Service, Auburn University, Auburn, AL 36830.

72. *Dune Building and Stabilization with Vegetation*, by W. W. Woodhouse, Jr., 1978. This report includes a section on the plants and planting methods needed to build and stabilize dunes in the Gulf Coast region. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 (request stock no. 008-022-00124-7; price: $3.00).

The following vegetation studies and reports are for other states but are applicable to the Alabama-Mississippi coast.

73. *Dune Restoration and Revegetation Manual*, by Jack Salmon, Don Henningsen, and Tom McAlpin, 1982. This is the most recent Florida Sea Grant Program advisory publication on dune restoration and maintenance. Available as SGR-48 from the Marine Advisory Program, G022 McCarty Hall, University of Florida, Gainesville, FL 32611 (price: $2.00).

74. *Stabilizing Beaches and Dunes with Vegetation in Florida.* A 2-page Marine Advisory Program information sheet for property owners and developers, the information is extracted from the more detailed Sea Grant Report Number 7 listed below (reference 75). Topics include the role of plants, vegetation zones, preservation and restoration, and suggestions for plantings. Free from the Marine Advisory Program, G022 McCarty Hall, University of Florida, Gainesville, FL 32611.

75. *Stabilization of Beaches and Dunes by Vegetation in Florida*, by J. H. Davis, Jr., 1975. A more detailed treatment of the role of plants in building and holding dunes, plant types, how vegetation indicates the setback line, and how to use plantings to preserve or restore dunes. Different regions and the associated plants are noted, and suggestions for the use of sand fencing in conjunction with plantings are outlined. Other references and sources of information are listed. Available as Report Number 7 from the Marine Advisory Program, G022 McCarty Hall, University of Florida, Gainesville, FL 32611.

76. *Salt Tolerant Plants for Florida Landscapes*, by W. E. Barrick, 1979. A good companion reference to the report listed

above (reference 75). Sixty-one different trees, palms, shrubs, ground cover, and vines are illustrated and briefly described, including their growth rates and hardiness with respect to Florida's 3 climatic zones. Salinity tolerance of plants is discussed, and soil-conditioning suggestions are given to help minimize soil salinity problems. Plant information is indexed and tabled for convenient summary, and additional references are provided. Ask for Report Number 28 and the accompanying list of commercial sources of salt-tolerant vegetation from the Marine Advisory Program, G022 McCarty Hall, University of Florida, Gainesville, FL 32611, or contact your county marine agent through the cooperative extension service for a copy or additional advice on plantings.

77. *Building and Stabilizing Coastal Dunes with Vegetation* (UNC-SG-82-05) and *Planting Marsh Grasses for Erosion Control* (UNC-SG-81-09), by S. W. Broome, W. W. Woodhouse, Jr., and E. D. Seneca, 1982. These recent publications on using vegetation as stabilizers are available from UNC Sea Grant, Box 8605, North Carolina State University, Raleigh, NC 27695. State publication number with your request.

78. *The Dune Book: How to Plant Grasses for Dune Stabilization*, by Johanna Seltz, 1976. Brochure outlining the importance of sand dunes and means of stabilizing them through grass plantings. Available from UNC Sea Grant, Box 8605, North Carolina State University, Raleigh, NC 27695.

79. *Shore Stabilization with Salt Marsh Vegetation*, by P. L. Knutson and W. W. Woodhouse, Jr., 1983. Summarizes the use of coastal marsh vegetation as an erosion control measure. Artificial plantings are often a good alternative to building protective structures against erosion of low-energy or sheltered shorelines, such as in bays, sounds, lagoons, and estuaries. The publication outlines criteria for determining site suitability for planting, selection of plant types, planting procedures, and estimating costs. The Special Report No. 9 is available from the U.S. Army Corps of Engineers and is an update of earlier work by Woodhouse and others (for example, "Propagation and Use of *Spartina alterniflora* for Shoreline Erosion Abatement," 1976, CERC Technical Report 76-2). Both reports and additional information on coastal stabilization are available from the U.S. Army Corps of Engineers, Coastal Engineering Research Center, Kingman Building, Fort Belvoir, VA 22060, or write to NTIS, Attn: Operations Division, 5285 Port Royal Road, Springfield, VA 22161, and request publication by title, author, and year. There is a charge for these publications.

80. *Vegetation Establishment and Shoreline Stabilization: Galveston Bay, Texas*, by J. W. Webb and J. D. Dodd, 1976. This study evaluates plants as shoreline stabilizers in a low-energy estuarine environment in Texas. The results may be pertinent to similar environments along the Alabama-Mississippi shore. Available as CERC Technical Paper 76-13 from the U.S. Army Corps of Engineers, Coastal Engineering Research

Center, Kingman Building, Fort Belvoir, VA 22060, or write to NTIS, Attn: Operations Division, 5285 Port Royal Road, Springfield, VA 22161.

Site analysis

81. *Inventory of Basic Environmental Data—Alabama*, prepared by the U.S. Army Corps of Engineers, Mobile District, and the Alabama Office of State Planning and Federal Programs, State Planning Division, January 1981. Shows areas of erosion and deposition along the coast as well as flood-prone areas. Copies should be available through those offices.

82. *The Mississippi Gulf Coast Comprehensive Development after Camille*, by the State of Mississippi, 1970. The plan outlines a post-Camille reconstruction in 3 parts: strategy for redevelopment, the Gulf Coast Development and Services Corporation, and program areas. Of particular interest are the Camille damage data, the "inundation areas" map that can be used for future site evaluation, and comparison of the recommendations of the study with what has been done. Copies may still be available for inspection in planning offices.

83. *Building Construction on Shoreline Property*, by C. A. Collier. Homeowners and prospective buyers of coastal property will find this pamphlet to be a handy checklist in evaluating location, elevation, building design and construction, utilities, and inspection. Available free from either the Marine Advisory Program, G022 McCarty Hall, University of Florida, Gainesville, FL 32611, or the Florida Department of Natural Resources, Bureau of Beaches and Shores, 202 Blount Street, Tallahassee, FL 32304.

84. *Handbook: Building in the Coastal Environment*, by R. T. Segrest and associates, 1975. A well-illustrated, clearly and simply written book on Georgia coastal zone planning, construction, and selling problems. Topics include vegetation, soil, drainage, setback requirements, access, climate, and building orientation. Includes a list of addresses for agencies and other sources of information. Much of the information applies to the Gulf Coast. Available from the Graphics Department, Coastal Area Planning and Development Commission, P.O. Box 1316, Brunswick, GA 31520.

Conservation, planning and regulation

85. *Questions and Answers on the National Flood Insurance Program*, by the Federal Emergency Management Agency (FEMA), 1983. This pamphlet explains basics of flood insurance and provides addresses of FEMA offices. Free from FEMA, Washington, DC 20472.

86. *Development of the Coast: Facing the Tough Issues*, a Coastal States Organization conference held in Charleston, 1979. These published final proceedings give an abbreviated overview of the wide range of problems generated by coastal development. Available from CSO, Conference Management Associates, Ltd., 1044 National Press Building, Washington, DC 20045.

87. *The Alabama Coastal Area Management Program and Final Impact Statement*, by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of Coastal Zone Management, and the Alabama Coastal Area Board, 1979. This governing document for the Alabama Coastal Zone Management Program defines permitting and enforcement procedures within the area of management. Although it may not be of interest to the general reader, anyone involved in planning and development should be familiar with this publication. Copies should be available through local planning offices as well as the Alabama Department of Environmental Management, State Capital, Montgomery, AL 36130.

88. *Building in the Coastal Counties: A Guide to the Permitting Process with Special Emphasis on the Coastal Area*, 1984. This edition is recommended reading for anyone in the coastal zone of Alabama who is considering building a house, installing or modifying a septic system, drilling a well, or engaging in any construction or water discharge activity in wetlands or waterways. The booklet provides an outline of required permits, steps in obtaining permits, and addresses of all federal, state, and local agencies that must be contacted. A few minutes spent in reading this guide may save you hours of work, and it may help avoid penalties for not following the law. Available from the Permit Coordination Center, Alabama Department of Environmental Management, State Capital, Montgomery, AL 36130 (phone: [205] 277–3630).

89. *Mississippi Coastal Program*, by the Bureau of Marine Resources, Mississippi Department of Wildlife Conservation, 1980. This is the governing document for Mississippi's Coastal Zone Management Program, including wetlands and fisheries. Rules, regulations, guidelines, and permitting procedures are listed. People involved in planning and development within the coastal zone should be familiar with this publication. Copies should be available through local planning offices as well as the Bureau of Marine Resources, Mississippi Department of Wildlife Conservation, P.O. Box 959, Long Beach, MS 39560 (phone: [601] 864–4602).

90. *Mississippi Coastal Area: Its Future*, 1975, and *Mississippi Coastal Resources: A Survey to Determine Attitudes and Opinions of Local Citizens*, 1976. These short, descriptive brochures dealing with coastal planning are available from the Mississippi-Alabama Sea Grant Consortium, Caylor Building, Gulf Coast Research Laboratory, Ocean Springs, MS 39564.

91. *A Survey of Wetlands Law, Effects of Hurricane Camille on the Economy of Harrison County*, and *Economic-Ecologic Model for Mississippi-Alabama Coastal Counties* are 3 representative titles of the many legal and socioeconomic studies available from the Mississippi-Alabama Sea Grant Consortium, Caylor Building, Gulf Coast Research Laboratory, Ocean Springs, MS 39564. Write for their free list of titles, or call (601) 875–9341.

92. *Mississippi Guide to Saltwater Fishing Regulations*, 1983. A digest of regulations for sport and commercial fishing in the marine waters of Mississippi, including shellfish. The pamphlet includes a list of endangered and protected species and where to call if you find such animals stranded. Available from the Department of Wildlife Conservation, Bureau of Marine Resources, P.O. Drawer 959, Long Beach, MS 39560; phone (601) 864-4602.

93. *Dauphin Island: At the Crossroads of Decision*, by Cy Rhode, 1980 and 1981. This study was published in *Mobile Magazine* in 4 parts, beginning with the November-December 1980 issue. The author traces the storm history of the island, the impact of Hurricane Frederic in terms of physical damage (144 homes with total loss or major damage; 856 homes with severe damage) and dollar loss; he compares Frederic to a similar 1906 storm to illustrate that development set the stage for this staggering loss. The loss of the causeway to the island is examined as an opportunity to assess options other than bridge replacement; and the replacement cost in terms of federal subsidies is documented. Part III reviews the island's general problems associated with population growth, including marshland filling, poor sanitation, saltwater intrusion, and similar problems. The conclusion outlines a study program for planning. However, only time will tell if this good advice is heeded. This article is recommended reading to all coastal property owners, and taxpayers in general. Contact *Mobile Magazine*, Mobile Area Chamber of Commerce. Also available from Coastal Zone Studies, University of West Florida, Pensacola, FL 32504.

94. *Relief from Disaster Relief: Report from Dauphin Island*, by Tom Horton, 1981. This short article captures the socioeconomic dilemma of the danger of barrier beach development and who should pay for the inevitable post-storm reconstruction. Expenditures of federal tax dollars in post-Frederic reconstruction averaged more than $50,000 for each of the 650 permanent structures on Dauphin Island, according to the article. Such costs plus other hidden subsidies realized in the aftermath of Hurricane Frederic are resulting in a tightening of federal programs. This article appeared in the *Amicus Journal* (summer 1981, pp. 22-25).

95. *Barrier Islands*, by H. C. Miller, 1981. Published in *Environment* (vol. 23, no. 9, pp. 6-11, 36-42), this is an excellent review of how the federal government has stimulated barrier island development and the resulting losses in tax dollars.

96. *The Law of the Coast in a Clamshell*, by Peter H. F. Graber. These articles in *Shore and Beach* magazine on the contemporary law of the coast were written for nonattorneys. The initial article presents an overview (vol. 48, no. 4, pp. 14-20), followed by "The Federal Government's Expanding Role" (vol. 49, no. 1, pp. 16-20) and articles for each coastal state. *Shore and Beach* should be available through your library on interlibrary loan.

97. *The Water's Edge: Critical Problems of the Coastal Zone*, edited by B. H. Ketchum, 1972. Scientific summary of coastal zone problems. Published by M.I.T. Press, Cambridge, MA 02139.

98. *Design with Nature*, by Ian McHarg, 1969. A now-classic text on the environment. Stresses that when man interacts with nature, he must recognize its processes and governing laws while realizing that such interaction both presents opportunities for and requires limitations on human use. Published by Doubleday and Co., Garden City, NY 11530.

99. *Who's Minding the Shore*, by the Natural Resources Defense Council, Inc., 1976. A guide to public participation in the coastal zone management process. Defines coastal ecosystems and outlines the Coastal Zone Management Act, coastal development issues, and means of citizen participation in the coastal zone management process. Lists sources of additional information. Available from the Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, 3300 Whitehaven Street, N.W., Washington, DC 20235.

100. *Ecological Determinants of Coastal Area Management*, by Francis Parker, David Brower, and others, 1976. Volume 1 defines the barrier island and related lagoon-estuary systems and the natural processes that operate within them. Outlines man's disturbing influences on island environments and suggests management tools and techniques. Volume 2 is a set of appendixes that includes information on coastal ecological systems, man's impact on barrier islands, and tools and techniques for coastal area management. Also contains a good barrier island bibliography. Available from the Center for Urban and Regional Studies, University of North Carolina, 108 Battle Lane, Chapel Hill, NC 27514.

101. *The Fiscal Impact of Residential and Commercial Development: A Case Study*, by T. Muller and G. Dawson, 1972. A classic study which demonstrates that development may ultimately increase, rather than decrease, community taxes. Available from The Publications Office, the Urban Institute, 2100 M Street, N.W., Washington, DC 20037 (price: $3.00). Refer to URI-22000 when ordering.

102. *Report of the Conference on Marine Resources of the Coastal Plains States*, 1974. Collection of papers presented at a meeting in Wilmington, North Carolina. Topics include seabed mineral resources, sport fishing, recreation and tourism, and coastal zone planning. Of special interest is a paper entitled "Reasonable Development and Reasonable Conservation," by David Stick. Sponsored and published by the Coastal Plains Center for Marine Development Services.

103. *Coastal Ecosystem Management*, by John Clark, 1977. This 928-page text covers most aspects of the coastal zone from descriptions of processes and environments to legal controls and outlines for management programs. Essential reading for planners and beach community managers. Published by John Wiley and Sons, New York. (The 1983 reprint with correc-

tions is available from Krieger Publishing Co., P.O. Box 9542, Melbourne, FL 32902 for $59.50 postpaid).

104. *Coastal Environmental Management*, prepared by the Conservation Foundation, 1980. Guidelines for conservation of resources and protection against storm hazards, including ecological description and management suggestions for coastal uplands, floodplains, wetlands, banks and bluffs, dunelands, and beaches. Part II presents a complete list of federal agencies and their authority under the law to regulate coastal zone activities. A good reference for planners and persons interested in good land management. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

105. *Coastal Affair*, edited by Jennifer Miller, 1982. A special subject issue of *Southern Exposure* magazine (vol. X, no. 3), that explores a wide range of coastal issues from the physical to the social and economic. Available from *Southern Exposure*, P.O. Box 531, Durham, NC 27702 (price: $4.00).

106. *Patterns and Trends of Land Use and Land Cover on Atlantic and Gulf Coast Barrier Islands*, by H. F. Lins, Jr., 1980. U.S. Geological Survey, Professional Paper 1156, available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, or through your local college or university library.

Building or improving a home

Both current and prospective owners and builders of homes in hurricane-prone areas should supplement the information and advice provided in this book with that offered in references dealing specifically with safe construction. These excellent references contain sound, useful information that should help the residents of such areas minimize losses caused by extreme wind or rising water. Many of these publications are free. The government publications are paid for by your taxes, so why not use them? The following references are recommended to those readers who wish to investigate further the subject of hurricane-resistant construction.

107. *Coastal Design: A Guide for Planners, Developers, and Homeowners*, by Orrin H. Pilkey, Jr., Orrin H. Pilkey, Sr., Walter D. Pilkey, and William J. Neal, 1983. A detailed companion volume and construction guide expanding on the information outlined in this text. Chapters include discussions of shoreline types, individual residence construction, making older structures storm-worthy, high-rise buildings, mobile homes, coastal regulations, and the future of the coastal zone. Published by Van Nostrand Reinhold Co., New York (price: $25.00).

108. *Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas*, prepared by Dames and Moore for HUD, on behalf of the Federal Emergency Management Agency, 1981. A guide to the coastal environment

with recommendations on site and structure design relative to the National Flood Insurance Program. The report includes design considerations, examples, construction costs, and appendixes on design tables, bracing, design worksheets, wood preservatives, and a listing of useful references. The manual is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 (publication number 722-967/545), or contact a FEMA office.

109. *Elevated Residential Structures, Reducing Flood Damage Through Building Design: A Guide Manual*, prepared by the Federal Insurance Administration, 1984. An excellent outline of the flood threat and necessity for proper planning and construction. Illustrates construction techniques and includes glossary, references, and worksheets for estimating building costs. Order publication 0-438-116 from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, or contact an office of the Federal Emergency Management Agency.

110. *Flood Emergency and Residential Repair Handbook*, prepared by the National Association of Homebuilders Research Advisory Board of the National Academy of Science, 1980. Guide to floodproofing as well as step-by-step cleanup procedures and repairs, including household goods and appliances. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Order stock no. 023-000-00552-2 (price: $3.50).

111. *Wind-Resistant Design Concepts for Residences*, by Delbart B. Ward. Displays with vivid sketches and illustrations construction problems and methods of tying structures to the ground. Considerable text and excellent illustrations devoted to methods of strengthening residences. Offers recommendations for relatively inexpensive modifications that will increase the safety of residences subject to severe winds. Chapter 8, "How to Calculate Wind Forces and Design Wind-Resistant Structures," should be of particular interest to the designer. Available as TR83 from the Civil Defense Preparedness Agency, Department of Defense, The Pentagon, Washington, DC 20301, or from the Civil Defense Preparedness Agency, 2800 Eastern Boulevard, Baltimore, MD 21220.

112. *Interim Guidelines for Building Occupant Protection from Tornadoes and Extreme Winds* (TR83A) and *Tornado Protection—Selecting and Designing Safe Areas in Buildings* (TR83B). These are supplement publications to the above reference (111) and are available from the same address.

113. *Southern Standard Building Code*. Available from Southern Building Code Congress, 1116 Brown Marx Building, Birmingham, AL 35203, or Southern Building Code Publishing Company, 3617 8th Avenue South, Birmingham, AL 35222.

114. *The Uniform Building Code*. Available from International Conference of Building Officials, 5360 South Workman Mill Road, Whittier, CA 90601.

115. *Protecting Mobile Homes from High Winds*, prepared by the Civil Defense Preparedness Agency, 1974. An excellent booklet that outlines methods of tying down mobile homes and means of protection such as positioning and windbreaks. Publication 1974-0-537-785, available free from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, or from the U.S. Army, AG Publications Center, Civil Defense Branch, 2800 Eastern Boulevard (Middle River), Baltimore, MD 21220.

116. *Structural Failures: Modes, Causes, Responsibilities*, 1973. See especially the chapter entitled "Failure of Structures Due to Extreme Winds" (pp. 49–77). Available from the Research Council on Performance of Structures, American Society of Civil Engineers, 345 East 47th Street, New York, NY 10017 (price: $4.00).

117. *Hurricane-Resistant Construction for Homes*, by T. L. Walton, Jr., 1976. An excellent booklet produced for residents of Florida but equally as useful to those on the Gulf coast. A good summary of hurricanes, storm surge, damage assessment, and guidelines for hurricane-resistant construction. Technical concepts are presented on probability and its implications on home design in hazard areas. A brief summary of federal and local guidelines is given. Available from Florida Sea Grant Publications, Florida Cooperative Extension Service, Marine Advisory Program, Coastal Engineering Laboratory, University of Florida, Gainesville, FL 32611.

118. *Guidelines for Beachfront Construction with Special Reference to the Coastal Construction Setback Line*, by C. A. Collier and others, 1977. Report no. 20, available from Florida Sea Grant Publications, Florida Cooperative Extension Service, Marine Advisory Program, Coastal Engineering Laboratory, University of Florida, Gainesville, FL 32611.

119. *Houses Can Resist Hurricanes*, by the U.S. Forest Service, 1965. An excellent paper with numerous details on construction in general. Pole-house construction is treated in particular detail (pp. 28–45). Available as Research Paper FPL 33 from Forest Products Laboratory, Forest Service, U.S. Department of Agriculture, P.O. Box 5130, Madison, WI 53705.

120. *Pole House Construction and Pole Building Design*. Available from the American Wood Preservers Institute, 1651 Old Meadows Road, McLean, VA 22101.

121. *Standard Details for One-Story Concrete Block Residences*, by the Masonry Institute of America. Contains 9 foldout drawings that illustrate the details of constructing a concrete block house. Principles of reinforcement and good connections presented are aimed at design for seismic zones but apply to design in hurricane zones as well. Written for both layman and designer. Available as Publication 701 from Masonry Institute of America, 2550 Beverly Boulevard, Los Angeles, CA 90057 (price: $3.00).

122. *Masonry Design Manual*, by the Masonry Institute of America. An oversized 384-page manual that covers all types of

masonry, including brick, concrete block, glazed structural units, stone, and veneer. Very comprehensive and well presented. Probably of more interest to the designer than to the layman. Available as Publication 601 from the Masonry Institute of America, 2550 Beverly Boulevard, Los Angeles, CA 90057 (price: $14.00).

123. *Model Minimum Hurricane-Resistant Building Standards for the Texas Gulf Coast*. Although written specifically for the Texas coast, the conditions are similar enough that this publication is appropriate for the Alabama-Mississippi coast. Available from the Texas Coastal and Marine Council, P.O. Box 13407, Austin, TX 78711.

124. *Construction Materials for Coastal Structures*, by Moffatt and Nichol, Engineers, 1983. A lengthy (427-page) summary of the properties and uses of a wide range of materials employed in coastal structures, beach protection devices, and erosion control. This technical reference should be of particular interest to coastal engineers and construction contractors who build such structures. Request Special Report No. 10, U.S. Army Corps of Engineers, Coastal Engineering Research Center, Kingman Building, Fort Belvoir, VA 22060.

125. *Coastal Construction Building Code Guidelines*, edited by R. R. Clark, 1980. Although developed for Florida, these guidelines are applicable to the rest of the Gulf Coast and make specific recommendations to strengthen the Standard Building Code in coastal areas. Available as Technical Report No. 80-1, Bureau of Beaches and Shores, Florida Department of Natural Resources, 3900 Commonwealth Boulevard, Tallahassee, FL 32303.

Index

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Living with the Alabama-Mississippi shore

The Alabama-Mississippi shoreline along the Gulf of Mexico boasts some of the world's most beautiful beaches and balmiest climes. Ever-increasing numbers of retirees, recreation lovers, and industries with their work forces are being attracted to the "Sun Belt." On a soft April day the Gulf's waters look as peaceful as a pond.

Yet this same serene shoreline has been ravaged by seven major hurricanes during this century. Several years more than one fearful storm has come hurtling in during a single "season." Loss of life and property damage have been devastating. And newcomers seem almost unaware of the potential dangers.

The authors of this book offer a vivid, historical overview for understanding the environment of the Alabama-Mississippi shore. They describe the risks faced by new residents, and they point the way toward safe and sane coastal development.

Written for the layman, this richly illustrated volume includes:

- Specific guidelines for building and buying at the shore with maximum protection for your investment and yourself;
- Site-safety maps and descriptions for every stretch along the coastline from Perdido Key to Bay St. Louis in enough detail to help you find your specific homesite;
- Up-to-date advice on land use and the law;

Duke University Press   Durham, North Carolina

- Easy-to-follow discussion of the dynamics of shoreline change;
- Ways to guard yourself from the hazards of hurricanes;
- Photographs, drawings, maps, and checklists for further reading;
- And guides to federal, state, and local agencies involved in coastal development that will be of value to the homeowner, planner, or developer.

This volume is the eighth book in the **Living with the shore series**, which will include more than twenty books on coastal living and management, to be published under the general editorship of Orrin H. Pilkey, Jr., Duke University, and William J. Neal, Grand Valley State College of Michigan. Ultimately the series will cover the entire Atlantic and Pacific shorelines as well as the Great Lakes. In addition, Duke University Press has reissued in a new edition *The Beaches are Moving: The Drowning of America's Shoreline*, by Wallace Kaufman and Orrin H. Pilkey, Jr., which serves as an introduction and background to the series, covering the basic issues that are applied to specific coastlines in the volumes of the series.

The series editors also have written *Coastal Design: A Guide for Builders, Planners, and Home Owners*, which concentrates on safe construction principles for builders (available from Van Nostrand Reinhold Co., Inc.).

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